Osteoporosis International (2023) 34:527–537
https://doi.org/10.1007/s00198-022-06636-z

ORIGINAL ARTICLE

Epidemiology of pelvic and acetabular fractures in the USA from 2007 to 2014

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Received: 23 January 2022 / Accepted: 5 December 2022 / Published online: 29 December 2022

Abstract

Summary Incidence of pelvic and acetabular fracture is increasing in Europe. From 2007 to 2014 in the USA, this study found an age-adjusted incidence of 198 and 40 fractures/100,000/year, respectively, much higher than what has been described before. Incidence remained steady over that period and only a small increase in incidence of pelvic fracture in men was identified.

Purpose To determine the incidence of pelvic ring and acetabular fractures in the USA over the period 2007–2014 and to examine trends over time.

Methods Retrospective population-based observational study using data from the Nationwide Emergency Department Sample (NEDS), a 20% stratified all-payer sample of US hospital–based emergency departments (EDs). All patients seen in the ED and diagnosed with pelvic/acetabular fracture from 2007 to 2014 were included. The primary outcome was age-adjusted incidence of pelvic and acetabular fractures per 100,000 persons/years. Secondary outcomes included incidence stratified by age and sex, patient- and hospital-related characteristics, and ED procedures. Tests for linear trends were used to determine if there were statistically significant differences by sex and age groups over time.

Results The age-adjusted incidence of pelvic fracture was 198 fractures/100,000/year, 323 in women and 114 in men. The age-adjusted incidence of acetabular fracture was 40 fractures/100,000/year, 36 in women and 51 in men. A small increase in the age-adjusted incidence of pelvic fracture in men was the only significant trend observed during the study time ($p = 0.03$). Over that period, the mean age of patients at presentation increased, as well as their number of comorbidities and associated fragility fractures, and they were more often sent home or to nursing facilities.

Conclusions When considering all patients coming to the ED, not only those admitted to the hospital, adjusted incidence of pelvic and acetabular fracture is much higher than what has been described before. Contrarily to the global increase seen in other countries, incidence of pelvic and acetabular fractures dropped in the USA from 2007 to 2014 and only a small increase in age-adjusted incidence of pelvic fracture in men was identified.

Keywords Acetabular fracture · Epidemiology · Nationwide Emergency Department Sample · Pelvic fracture · Trend

Introduction

Pelvic fractures constitute 2 to 8% of all fractures [1]. The overall incidence of pelvic fracture patients admitted to the hospital is 37/100,000 per year [1, 2], and it rises to 92/100,000 per year in people aged 65 years or older [3]. Its incidence is bimodal: there is a peak in young people, because of high-energy trauma, and another peak in the elderly, caused by low-energy falls and pre-existing osteoporosis [2, 4–6]. Acetabular fractures often coexist with pelvic fractures and epidemiology articles frequently describe them

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together [7]. Both fractures have important consequences, especially in the older adult [8, 9].

Pelvic and hip fractures are commonly associated with age [10–12]. It is expected that the percentage of the population aged 65 and over will increase from 15% in 2014 to 24% in 2060 [13], in parallel with age-associated diseases. Moreover, an increase in age-adjusted incidence of low-trauma pelvic fracture has been described internationally [1, 14–17], especially in the older adult population. If the increasing trend in number and age-adjusted incidence continues, the number of low-energy pelvic fractures in 2030 will be 2.4 times higher than in 2013 [14].

Describing the epidemiology of pelvic fracture is a complex task for two reasons. The first is that this fracture affects several bones, thus affecting the definition of "pelvic fracture" across studies. The second reason is that patients with a pelvic fracture do not always require admission; therefore, we would have to detect all cases in the emergency department (ED), if we were to have an accurate picture of the epidemiological situation of such fractures in the USA.

There are some epidemiological studies about pelvic and acetabular fractures in the general population, most of them from the North of Europe and Australia, using prospective local or national registries, and most of them using data only from patients admitted to the hospital [3–5, 14–24]. There are no studies that adequately report the incidence of pelvic ring and acetabular fractures in the USA. While some studies use hospital admission data [1, 2, 7, 25–28], there is no comprehensive study to evaluate the overall incidence of these injuries.

We hypothesized that the age-adjusted incidence of pelvic and acetabular fracture in the USA increased from 2007 to 2014. Therefore, we undertook this epidemiology study with the following aims: (1) to calculate the trend in age-adjusted incidence of pelvic and acetabular fracture from 2007 to 2014, (2) to calculate the trend in incidence of pelvic and acetabular fracture stratified by age group (≤ 64, 65–84, and ≥ 85 years old), and (3) to compare patient- and hospital-related characteristics, ED procedures and outcomes, and discharge disposition at the beginning and by the end of the time period under evaluation (2007–2008 versus 2013–2014).

Methods

Study design, data source, and population

We conducted a retrospective population-based observational study using data from the Nationwide Emergency Department Sample (NEDS) from 2007 to 2014 [29]. NEDS is part of a series of databases created for the Healthcare Cost and Utilization Project (HCUP), sponsored by the US Agency for Healthcare Research and Quality (AHRQ). It is considered the largest all-payer ED database, capable of providing national estimates, and approximates a 20% stratified sample of US hospital–based EDs and a 20% stratified sample of all discharges from US community hospitals, excluding rehabilitation and long-term acute care hospitals.

All patients seen in the ED and diagnosed of pelvic or acetabular fracture (all-listed diagnoses) from 2007 to 2014 were included in the study. We identified patients with pelvic and acetabular fractures based on the following International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes: 808.0/0.1 fracture of the acetabulum closed/open; 808.2/0.3 fracture of the pubis closed/open; 808.4 closed fracture of other specified parts of the pelvis; 808.41 closed fracture of the ilium; 808.42 closed fracture of the ischium; 808.43 multiple closed pelvic fractures with disruption of the pelvic circle; 808.44 multiple closed pelvic fractures without disruption of the pelvic circle; 808.49 closed fracture of other specified parts of the pelvis; 808.5 open fracture of other specified parts of the pelvis; 808.51 open fracture of the ilium; 808.52 open fracture of the ischium; 808.53 multiple open pelvic fractures with disruption of the pelvic circle; 808.54 multiple open pelvic fractures without disruption of the pelvic circle; 808.59 open fracture of other specified parts of the pelvis; 808.8/0.9 unspecified fracture of the pelvis closed/open. We included closed and open fractures, therefore low- and high-energy fractures (not only fragility osteoporotic fractures but also secondary to traffic accident or struck).

This study was reviewed and determined to meet the criteria for IRB exemption by Partners Human Research Committee.

Main outcome measures and other variables

The primary outcome of interest was age-adjusted incidence of pelvic and acetabular fractures per 100,000 patients per year. Secondary outcome measures included incidence stratified by age, patient- and hospital-related characteristics, and ED procedures.

Demographic variables included age, age group (≤ 64, 65–84, ≥ 85), sex (male, female), census region (Northeast, Midwest, South, and West), estimated median household income based on patients' ZIP code (< $37,999, > $64,000), hospital teaching status (metropolitan non-teaching, metropolitan teaching, and non-metropolitan), hospital trauma level designation (non-trauma center, trauma level I, trauma level II, trauma level III), and Charlson comorbidity index (0, 1, ≥ 2) [30]. Mechanism of injury (falling, motor vehicle, struck) was available starting in 2009 and included for years 2009–2010 and 2013–2014. We used the Injury Severity Score (ISS) variable, which is calculated by using the validated Stata module for ICD Programs for Injury Categorization (ICDPIC) [31], categorized as ≤ 9, 10–15, 16–25, or ≥ 26. Other covariates of interest included discharge disposition (home, transfer to short-term hospital, skilled nursing facility | intermediate care facility, other transfer, admitted, other, died), insurance status (Medicare, Medicaid, private, self-pay, no charge, other), and the following adverse events: acute kidney failure, acute myocardial infarction, pulmonary embolism, induced mental disorder, pneumonia, pulmonary insufficiency, deep venous thrombosis, intubation, blood transfusion. We included the following associated fractures based on ICD-9-CM diagnosis codes: femur (821, 820), femoral neck (820), head/face (959.0, 959.01), and chest/trunk (959.1, 959.11). We also included the following diagnostic ICD-9-CM procedure codes of interest: arteriography (88.40, 88.47) and endovascular (39.79), and the following surgical procedures: open reduction and internal fixation (79.30, 79.39), closed reduction and internal fixation (79.10, 79.39), external fixation (78.10, 78.1, 84.71, 84.72, 84.72), and internal fixation without reduction (78.50, 78.59).

Statistical analysis

We calculated incidence of pelvic/acetabular fracture from 2007 to 2014 and standardized to the age distribution of the year 2010 [32]. Trends in age-adjusted incidences from 2007 to 2014 were then graphically represented for pelvic and acetabular fractures, by sex. Additionally, annual incidences of pelvic/acetabular fractures from years 2007 to 2014 were calculated, stratified by age (≤ 64, 65–84, and ≥ 85 years old), and also graphically represented. We performed multivariable logistic regression with the year as a continuous covariate to test for trends and determine if there were statistically significant differences ($p < 0.05$) between rates of pelvic/acetabular fracture by sex and by age groups over time.

We compared patient- and hospital-related characteristics for two periods, from 2007 to 2008 and 2013 to 2014, to evaluate whether there was any change in the features of patients and hospitals over time. All counts and means were weighted using NEDS-provided design weights, accounting for patient clustering within hospitals and stratifying by hospital to obtain nationally weighted estimates. We used the chi-squared test to compare categorical variables and Student's *t*-test to compare continuous variables. All statistical testing was 2-sided, at a significance level of 0.05. We used SAS 9.4 version (SAS Institute Inc., Cary, NC) for all analyses.

Results

Study population

A total weighted sample of 1,124,016 patients with pelvic or acetabular fractures who came to the ED between 2007 and 2014 was identified. The mean age was 64.1 years, with a standard deviation (SD) of 0.4. Half the patients (48.1%) were older than 75 years, and almost a third of all patients (27%) were older than 85 years. Females sustained 63.2% of all fractures.

The absolute number of pelvic fractures per 100,000 increased from 262,910 in 2007–2008 to 267,334 in 2013–2014, representing an increase of 1.7% ($p < 0.001$). The absolute number of acetabular fractures per 100,000 increased from 180,437 in 2007–2008 to 182,341 in 2013–2014 ($p < 0.001$), representing an increase of 1%.

The majority of the fractures were pubic fractures (53.8%), followed by acetabular fractures (25.2%). In women, the most frequent fractures were pubic fractures (65.7%), followed by acetabular (15.7%), ilium (4.3%), ischium (2.4%), and multiple fractures (0.9%). In men, the most frequent fractures were acetabular fractures (41.5%), followed by pubic (33.4%), ilium (11.5%), ischium (2%), and multiple fractures (2%). Most of the fractures were closed (98.6%).

Age-adjusted incidence of pelvic and acetabular fracture

The age-adjusted incidence of pelvic fracture was 198 fractures/100,000/year, 323 in women and 114 in men (Fig. 1, blue line). The age-adjusted incidence of acetabular fracture was 40 fractures/100,000/year, 36 in women and 51 in men (Fig. 2, blue line). Regarding temporal trends, the only significant increase in the age-adjusted incidence rates during the study period was found in pelvic fracture in men (p of incidence trend = 0.03). No statistically significant trend was observed in pelvic fracture incidence in women ($p = 0.54$) or in acetabular fracture incidence ($p = 0.32$ in women; $p = 0.10$ in men).

Incidence of pelvic and acetabular fracture stratified by age

Women 85 or older had the highest incidence of pelvic fracture—796 fractures/100,000/year (SD 14) (Fig. 1a). Women of 65–84 years had a pelvic fracture incidence of 160 fractures/100,000/year (SD 8). Finally, incidence of pelvic fracture in the youngest group of female patients was around 15 fractures/100,000/year (SD 1). Regarding temporal trends by age group, incidence of pelvic fracture in women significantly dropped over time ($p < 0.001$) except in women older than 85 years ($p = 0.17$).

Incidence of pelvic fracture in men was 3 times lower than in women in both age groups: men 85 years or older—270 fractures/100,000/year (SD 9)—and men of 65–84 years—54 fractures/100,000/year (SD 3) (Fig. 1b). Incidence of pelvic fracture in the youngest group of men was similar

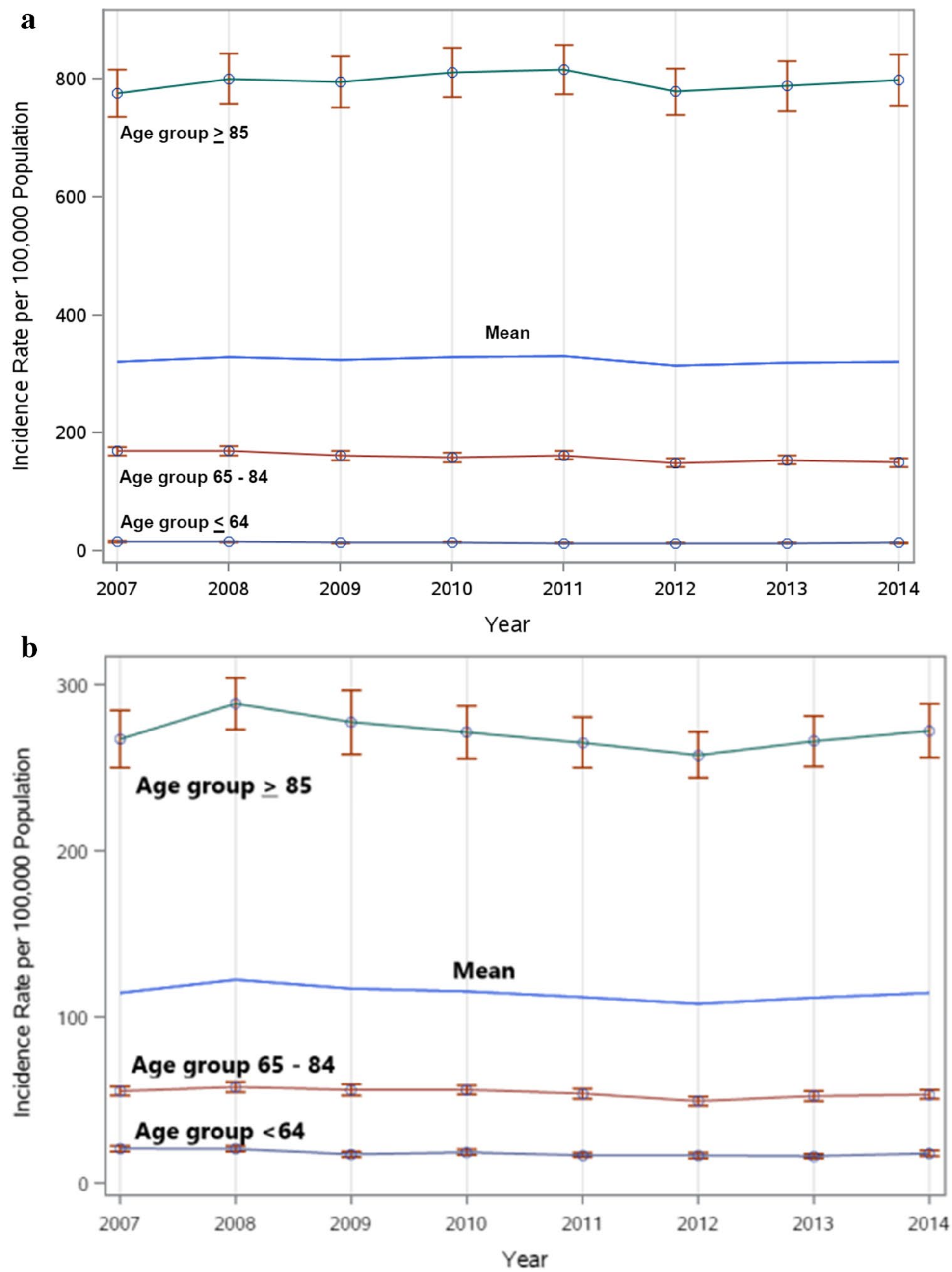

Fig. 1 Trend in age-adjusted pelvic fracture incidence (blue line). Temporal trends in pelvic fracture incidence stratified by age. For women (**a**) and men (**b**)

to women—18 fractures/100,000/year (SD 2). There was a statistically significant temporal trend in all age groups (≤ 64, 65–84, and ≥ 85 years old) for pelvic fracture in men ($p < 0.001$), and overall ($p = 0.03$). Please refer to Tables 3 and 4 in the Appendix for additional information.

Acetabular fractures were, however, more frequent in men (Fig. 2a, b). Men 85 or older and those of age 65–84 years had an incidence 1.4 times higher—113 fractures/100,000/year (SD 7) and 28 fractures/100,000/year (SD 1), respectively (Fig. 2b)—than women of the same age—83 fractures/100,000/year (SD 2) and 21 fractures/100,000/year (SD 1), respectively (Fig. 2a). Incidence was also 2.2 times higher in the youngest men—11 fractures/100,000/year (SD 1)—compared to women—5 fractures/100,000/year (SD 0.4). Regarding temporal trends by age group, incidence of acetabular fractures significantly dropped over time in all age groups ($p < 0.001$), except in women older than 85 years ($p = 0.32$).

Comparison of patient- and hospital-related characteristics, ED procedures and outcomes, and discharge disposition

From 2007 to 2014, there was an increase in the mean age at presentation of patients with pelvic and acetabular

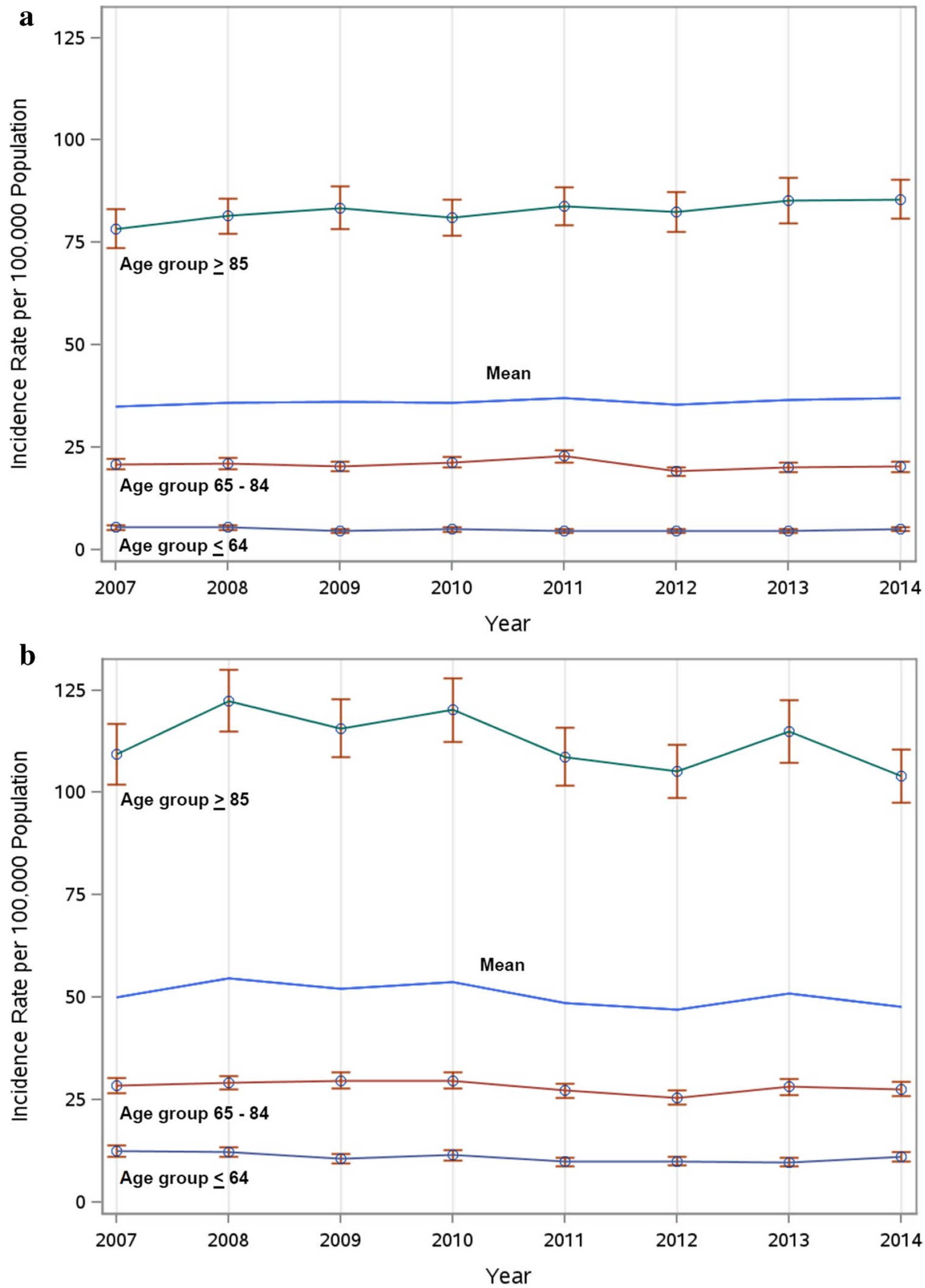

Fig. 2 Trend in age-adjusted acetabular fracture incidence (blue line). Temporal trends in acetabular fracture incidence stratified by age. For women (**a**) and men (**b**)

fractures of 1.9 and 3.7 years, respectively (Table 1). The group of patients older than 85 years had the highest increase, reaching 29% and 25% of all patients respectively by the end of the period. Besides, an increase of 3.4% in the number of patients with a Charlson index ≥ 2 depicts a population which was not only increasingly older, but also more clinically complex. Most of the fractures occurred in Southern states and that percent was 2% higher by the end of the study time. Near 30% of the patients were admitted to the ED during the weekend (data not shown).

Importantly, over the 8 years, more patients were transferred to level I and II trauma centers—reflecting an increase of 9.6% in pelvic and 10.1% in acetabular fractures.

More than 50% of the fractures were the consequence of a fall, and around 75% of all patients had an Injury Severity Score of 9 or less, probably because of low-impact trauma. Both features had an upward trend by the end of the period. Between 7 and 9% of the patients also had a fracture of the femur.

Table 1 Comparison of characteristics of pelvic and acetabular fracture patients between 2007–2008 and 2013–2014

		Pelvic		Acetabular	
		2007–2008 (*n*=262,910)	2013–2014 (*n*=267,334)	2007–2008 (*n*=180,437)	2013–2014 (*n*=182,341)
Age, mean (SD)		64.0 (0.6)	65.9 (0.4)	52.7 (0.6)	56.4 (0.5)
Age group, *n* (%)	≤ 64	97,290 (42.6)	99,873 (37.3)	87,308 (48.4)	78,790 (43.2)
	65–84	84,045 (32.0)	89,733 (33.6)	52,963 (29.4)	57,009 (31.3)
	≥ 85	66,639 (25.4)	77,691 (29.0)	40,076 (22.2)	46,523 (25.5)
Female, *n* (%)		168,116 (64.0)	176,284 (65.9)	102,822 (57.0)	107,258 (58.8)
Charlson index, *n* (%)	0	175,235 (66.6)	166,772 (62.4)	122,804 (68.1)	115,647 (63.4)
	1	48,866 (18.6)	51,486 (19.3)	32,217 (17.8)	34,881 (19.1)
	≥ 2	38,809 (14.8)	49,077 (18.4)	25,416 (14,1)	31,813 (17.4)
Region, *n* (%)	Northeast	43,839 (16.7)	44,390 (16.6)	29,108 (16.1)	29,538 (16.2)
	Midwest	67,357 (25.6)	61,682 (23.1)	46,376 (25.7)	42,029 (23.0)
	South	101,547 (38.6)	198,232 (40.5)	70,567 (39.1)	75,300 (41.3)
	West	50,167 (19.1)	53,031 (19.8)	34,386 (19.1)	35,474 (19.4)
Median income*, *n* (%)	< 37,999 $	65,996 (25.8)	71,087 (27.2)	45,168 (25.7)	49,792 (28.0)
	> 64,000 $	55,504 (21.7)	54,751 (21.0)	37,847 (21.6)	36,571 (20.5)
Hospital teaching status, *n* (%)	Metropolitan non-teaching	106,650 (40.6)	83,273 (31.1)	70,647 (39.1)	48,577 (26.6)
	Metropolitan teaching	115,920 (44.1)	145,813 (54.5)	84,164 (46.6)	110,018 (60.3)
	Non-metropolitan	40,340 (15.3)	38,248 (14.3)	25,627 (14.2)	23,746 (13.0)
Hospital trauma designation level, *n* (%)	Non-trauma center	135,905 (51.7)	97,464 (36.5)	86,562 (48.0)	62,257 (34.1)
	Trauma level I	50,863 (19.3)	63,346 (23.7)	40,339 (22.4)	49,862 (27.3)
	Trauma level II	23,717 (9.0)	37,979 (14.2)	17,494 (9.7)	27,157 (14.9)
	Trauma level III	17,448 (6.6)	26,593 (9.9)	11,395 (6.3)	18,805 (10.3)
Mechanism of injury#, *n* (%)	Falling	148,909 (58.0)	161,544 (60.4)	93,371 (53.2)	101,319 (55.6)
	Motor vehicle traffic	56,198 (21.9)	52,964 (19.8)	46,787 (26.7)	44,736 (24.5)
	Struck	4113 (1.6)	4114 (1.5)	2884 (1.6)	2980 (1.6)
ISS#, *n* (%)	≤ 9	201,867 (78.6)	212,167 (79.4)	133,525 (76.1)	140,066 (76.8)
	10–15	19,000 (7.4)	19,442 (7.3)	14,992 (8.5)	15,033 (8.2)
	16–25	24,994 (9.7)	24,269 (9.1)	18,824 (10.7)	18,455 (10.1)
	≥ 26	10,958 (4.3)	11,457 (4.3)	8157 (4.6)	8787 (4.8)
Associated fracture, *n* (%)	Femur fracture	7912 (3.0)	6276 (2.3)	6361 (3.5)	5287 (2.9)
	Femoral head	12,210 (4.6)	13,511 (5.0)	9882 (5.5)	10,846 (5.9)
	Head/face	3928 (1.5)	5892 (2.2)	2785 (1.5)	3907 (2.1)
	Chest/trunk	1769 (0.7)	1986 (0.7)	1326 (0.7)	1203 (0.7)

*Estimated median household income of residents in the patient's ZIP code

ISS, Injury Severity Score, calculated for years 2009–2010 and 2013–2014

All p values that compare clinical characteristics are < 0.01

Table 2 summarizes trends in diagnostic and surgical procedures and adverse events during the ED stay, as well as the expected primary payer. Diagnostic-therapeutic techniques were not usually required in the ED but their use increased over the years. Although these fractures are generally treated non-operatively, the most severe ones need immediate surgery and the procedure more frequently needed during the ED stay was the open reduction and internal fixation (ORIF), performed in 2 over 100 patients. From 2007 to 2014, an increasingly higher percentage of patients developed pulmonary insufficiency and acute kidney failure, the most frequent ED complications.

Regarding discharge disposition, from 2007 to 2014, less patients were admitted to the hospital, either pelvic fracture patients (decrease by 6.9%) or acetabular fracture patients (decrease by 4.5%). Consequently, more pelvic and acetabular patients were discharged directly home or to skilled nursing facilities over the study time. Around 0.4% of patients died during the ED stay.

Table 2 Comparison of procedures and adverse events in the ED, and discharge-related issues of pelvic and acetabular fracture patients between 2007–2008 and 2013–2014

		Pelvic		Acetabular	
		2007–2008 (*n* = 262,910)	2013–2014 (*n* = 267,334)	2007–2008 (*n* = 180,437)	2013–2014 (*n* = 182,341)
Diagnostic techniques in the ED, *n* (%)	Arteriography	< 11	24 (0.009)	0	12 (0.007)
	Endovascular repair	0	16 (0.006)	0	< 11
Surgical procedures in the ED, *n* (%)	ORIF	37 (0.01)	69 (0.03)	28 (0.02)	49 (0.03)
	CRIF	< 11	< 11	13 (0.007)	13 (0.007)
	ExFix	< 11	< 11	12 (0.006)	< 11
	InFix	< 11	0	< 11	0
Adverse event during ED stay, *n* (%)	AKF	8429 (3.2)	16,637 (6.2)	6195 (3.4)	11,524 (6.3)
	AMI	2066 (0.8)	2087 (0.8)	1382 (0.8)	1338 (0.7)
	PE	1381 (0.5)	1367 (0.5)	1010 (0.6)	1061 (0.6)
	Induced mental disorder	1498 (0.6)	1667 (0.6)	1120 (0.6)	1198 (0.7)
	Pneumonia	0	0	0	0
	Pulmonary insufficiency	9465 (3.6)	10,084 (3.8)	7479 (4.1)	8132 (4.5)
	DVT	2418 (0.9)	1878 (0.7)	1982 (1.1)	1508 (0.8)
	Intubation	1097 (0.4)	575 (0.2)	790 (0.4)	339 (0.2)
	Transfusion of blood	6354 (2.4)	4251 (1.6)	4424 (2.4)	2826 (1.5)
Disposition from ED, *n* (%)	Home	52,708 (20.0)	62,997 (23.6)	32,355 (17.9)	38.232 (21.0)
	Transfer to short-term hospital	14,787 (5.6)	15,532 (6.6)	11,497 (6.4)	13,718 (7.5)
	SNF, ICF, other transfer	7390 (2.8)	15,989 (6.0)	5115 (2.6)	9664 (5.3)
	Admitted	184,455 (70.1)	168,959 (63.2)	138,958 (70.0)	119,531 (65.5)
	Other	2356 (0.9)	885 (0.3)	1939 (1.0)	647 (0.3)
	Died	1225 (0.5)	973 (0.4)	1164 (0.6)	548 (0.3)
Expected primary payer, *n* (%)	Medicare	138,426 (52.8)	156,443 (58.7)	85,263 (47.4)	96,432 (53.1)
	Medicaid	17,597 (6.7)	21,469 (8.0)	13,091 (7.3)	16,495 (9.1)
	Private	72,230 (27.6)	60,817 (22.8)	54,759 (30.5)	47,072 (25.9)
	Self-pay	18,322 (7.0)	14,079 (5.3)	14,155 (7.9)	10,826 (6.0)
	No charge	799 (0.3)	741 (0.3)	590 (0.3)	541 (0.3)
	Other	14,610 (5.6)	13,104 (4.9)	11,830 (6.6)	10,312 (5.7)

ORIF, open reduction and internal fixation; *CRIF*, closed reduction and internal fixation; *ExFix*, external fixation; *InFix*, internal fixation without reduction; *AKF*, acute renal failure; *AMI*, acute myocardial infarction; *PE*, pulmonary embolism; *DVT*, deep venous thrombosis

Cells presented as "<" (less than); this is due to data restrictions of displaying cells less than 11

All p values that compare clinical characteristics are < 0.01

Finally, Medicare and Medicaid were the primary payer in more than 60% of the patients, and that percentage increased by the end of the study period.

Discussion

From 2007 to 2014 in the USA, this study found an age-adjusted incidence of 198 pelvic fractures/100,000/year pelvic and 40 acetabular fractures/100,000/year. Incidence remained steady during the whole period except for a small increase in pelvic fracture incidence in men.

The high incidence is in contrast with the results of other studies, although it seems difficult to establish a comparison due to the heterogeneity of patient selection and methodology used; for instance, some studies included only admitted patients, and not all coming to the ED; other included fractures of the pelvic ring alone not of the pelvis-acetabulum; other studies included only fragility fractures (osteoporotic fractures as a result of a fall from standing height in older adults) [14, 16]; there are studies which focused on other specific age segments (older than 70, older than 80 years); finally, other authors analyzed adjusted incidence, incidence or crude numbers.

As an example, we assumed that, when comparing our figures with those of the other articles, they were including all the fractures, the low- and high-impact ones, but there is no description of the fracture mechanism in any but in two studies [14, 16]. This heterogeneity, then, may affect the comparison of incidence figures. To illustrate this, we included all patients with a diagnosis of pelvic/acetabular fracture, by all mechanisms, either open or closed. When reviewing the US epidemiology literature regarding this topic, we found that the studies included only admitted and pelvic fracture patients [1, 27], only closed fractures [7], only admitted and unstable pelvic fracture patients [25], only pelvic fractures [26], and only admitted and severe fractures [28], or they were unicentric studies [2]. Buller described an adjusted incidence of 34.3 admitted pelvic fractures per 100,000 in the USA in 2007 [1]. Even if we had analyzed only the admitted ones (70% in our study), incidence would have remained higher. Only by including all patients with a pelvic/acetabular fracture coming to the ED, we could thoroughly describe the epidemiological situation of this fracture in the USA. This is particularly important in the elderly, a vulnerable age group frequently forgotten, even in some trauma registries [33].

Regarding the incidence trend, our study did not confirm the hypothesis that adjusted incidence was increasing from 2007 to 2014. That was another unexpected finding, given that other studies have described a progressive increase of incidence over time [1, 14, 16, 17], with a rate that cannot be explained merely by demographic changes. The steady incidence trend found in our study is similar to what has been observed in hip fracture incidence. Age-adjusted hip fracture incidence declined from 1995 to 2012 and then plateaued until 2015 [34, 35]. The incidence decrease coincided with the introduction of new diagnostic tools and bisphosphonates and other osteoporosis treatments from 1995 [34]. Some authors have warned that the incidence plateau observed in the last years in the USA [35] and internationally [36] could be due to several reasons: a decrease in the number of centers doing DXA testing (because of less reimbursement), a decrease in anti-osteoporosis prescriptions (due to fear of side effects or poor health education), the drug-holiday practice, or changes in population demographics (cohort effects cause by cohorts with different fracture incidences, different racial/ethnic distributions, etc.) [35, 37] However, a population decrease in the bone mineral density (BMD) has been found recently, and we should be vigilant to detect epidemiology changes in these and other fractures.

When looking at non-adjusted figures, the absolute number of pelvic and acetabular fractures increased around 1–1.7% by the end of the period. The increase is slightly more apparent in pelvic fractures, probably because those patients are mainly women and they have a longer life expectancy. Again, our data did not show the expected increase due to the aging of the population, in line with the steady trend of adjusted incidence described in our study. Other studies found an increase in absolute numbers when they analyzed the subgroup of elderly patients admitted to the hospital. Using data from the Nationwide Inpatient Sample (NIS) and analyzing only admitted patients with Medicare as the primary payer (83% were 65 years or older), Sullivan [7] found an increase of 67% of acetabular fractures and 24% of pelvic fractures from 1993 to 2010.

Regarding trends by age group, incidence of pelvic and acetabular fractures remained steady or slightly decreased over time in all age groups, except in the oldest group of men with pelvic fracture, with a small but significant trend of increasing incidence. Clement et al., as well as other authors, described an increase in incidence of pelvic fracture in elderly women [14, 16, 38, 39] that was not confirmed by our study.

This study also found that from 2007 to 2014, the mean age, comorbidity, and number of associated fragility fractures of patients increased; they also had less economic possibilities. By 2013–2014, around 40% were treated in level I–II trauma centers, and there was a decreasing trend in hospital admissions. After hospital stay, some centers provide their patients with written recommendations, and a 4–6-week follow-up appointment for the orthopedic trauma clinic—and, in some cases, for the Fracture Liaison Service (FLS). When patients are discharged directly from the ED, some centers lack a similar protocol. Although great efforts have been done in measuring patients' symptoms during the follow-up clinic appointment (for instance, the PROMIS initiative), the current health care systems do not ensure an appropriate measurement of pain interference, sarcopenia, functional recovery, frailty, and risk of falls, or a proper treatment of osteoporosis after the fracture. Besides, there is no information about their rates of readmission, institutionalization, or death within 1 year after the fracture, or a detailed description of the economic impact of their subsequent health care when these frail patients are not evaluated comprehensively. Given the profile of these patients, joining forces with other specialties in multidisciplinary teams—such as FLS and orthogeriatric units—will be mandatory in the near future.

This study is not without limitations. Patient data in the NEDS are deidentified, and therefore, analyses cannot account for patients that might potentially be included more than once. Misclassification of some fractures may result from inaccuracies in coding which are caused by difficulties in classifying some of these fractures [40], or also because estimates are based on all-listed diagnoses and not on the principal diagnosis responsible for the patient's admission to the hospital. There was no information about the length of stay in the ED. For instance, shorter ED LOS in 2014 compared to 2007 could affect the comparison of adverse event rates and mortality in the ED over time. There are potential biases—age, period, and cohort effects—that should be taken into account when evaluating population temporal trends [37], and the last two were not analyzed in this study.

The strength of this study includes using the largest ED database capable of providing national estimates of pelvic and acetabular fracture patients in the USA, which allowed us to get a real epidemiological picture of these fractures by capturing the most vulnerable population: elderly patients coming to the ED even with mild fragility fractures. That is certainly essential, given that nearly 3 in 4 older patients were left out of a sample of trauma registries [33]. Also, describing the changes in patients' profile along time and how they are managed nowadays in the ED was of great importance from a public health perspective.

Future research in this topic should include a close epidemiological follow-up to detect incidence trend variations, considering the recent trend change in diagnosis and treatment of osteoporosis. Those studies should consider the three potential biases associated with evaluating temporal trends at a population level [37]. To measure the true consequences of trauma in older adults, we must include in databases long-term outcomes beyond mortality, such as functional independence, cognition, and quality of life [41]. Finally, we should design studies that test the efficacy of comprehensive interventions on fragility fracture prevention, in order to change clinical practice and link that information with future epidemiological trend changes.

Conclusion

When considering all patients coming to the ED, and not only those admitted to the hospital, adjusted incidence of pelvic and acetabular fracture is much higher than what has been described before. Contrarily to the global increase seen in other countries, incidence of pelvic and acetabular fractures remained steady in the USA from 2007 to 2014, and only a small increase in age-adjusted incidence of pelvic fracture in men was identified. Over that period, the mean age of patients at presentation increased, as well as their number of comorbidities and associated fragility fractures, and they were more often sent home or to nursing facilities. These findings have a key impact toward resource allocation and prevention efforts for our aging population.

Appendix Results of temporal trends in pelvic and acetabular fracture incidence, by gender and age group

Table 3 Results of temporal trends in pelvic fracture incidence, by gender and age group

Gender	*p* value	Age group	*p* value
Women	0.54	≥ 85	0.17
		65–84	< 0.001
		< 65	< 0.001
Men	*0.03*	≥ 85	< 0.001
		65–84	< 0.001
		< 65	< 0.001

Table 4 Results of temporal trends in acetabular fracture incidence, by gender and age group

Gender	*p* value	Age group	*p* value
Women	0.32	≥ 85	0.32
		65–84	< 0.001
		< 65	< 0.001
Men	0.10	≥ 85	< 0.001
		65–84	< 0.001
		< 65	< 0.001

Acknowledgements Edited by Daniel Migueláñez Munilla.

Data availability Research data can be shared with third parties on request in order to verify the validity of the results. This could be in the form of raw data, samples, records, etc.

Declarations

Conflicts of interest Maria Loreto Alvarez-Nebreda, Michael J. Weaver, Tarsicio Uribe-Leitz, Marilyn Heng, Michael F. McTague, and Mitchel B. Harris declare that they have no conflict of interest. Dr. Heng is a consultant for Zimmer Biomet, Inc. Dr. Weaver is a consultant for OsteoCentric Technologies. On behalf of all authors, I certify that any financial interests such as employment, stock ownership, honoraria, paid expert testimony, as well as any personal relationship, academic competition, and intellectual passion which may inappropriately influence their actions have been disclosed.

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