Original Article

Epidemiology of atlas fractures in the United States: A 20-year analysis

ABSTRACT

Introduction: Fractures of the atlas represent a large portion of cervical spine trauma in the geriatric population. With an aging and more active population, it is expected that the number of patients sustaining atlas fractures is increasing. However, epidemiologic data regarding the incidence of atlas fractures in large populations are scarce. The aim of this study was to investigate the incidence and demographic characteristics of patients with fractures of the atlas in the United States (US) over the last 20 years.

Materials and Methods: This descriptive epidemiology study retrospectively analyzed the National Electronic Injury Surveillance System database to identify cases of atlas fractures presenting to US Emergency Departments (EDs) from 2001 to 2020. Annual and overall numbers of fractures and fracture incidence rates, patient demographics (age, gender, race), and injury characteristics (mechanism, associated injuries) were analyzed. Incidence rates are expressed as the number of fractures per million at-risk person-years. Patients were split into four different age groups for comparisons (<18, 18–64, 65–79, 80+ years).

Results: An estimated 38,092 cases of acute atlas fractures were identified, representing 11.1% of all cervical fractures and corresponding to an overall incidence rate of 6.2. Slightly more than half (54%) occurred in females and the mean age was 71 years. Overall, a majority (64%) of cases occurred in patients > 70 years old. There was substantial increase in incidence rate with age (<18 years: 0.7; 18–64 years: 2.6; 65–79 years: 17.1; 80 + years: 71.8). The most common injury mechanism was a low-energy fall (74%). Overall, only 42% of atlas fractures were isolated injuries, with 58% of patients sustaining at least one concomitant injury and 48% sustaining at least one additional fracture. Accounting for population growth yielded a significantly increasing incidence over the study period from 1.7 in 2001 to 13.4 in 2020 (annual percent increase = 11, $P < 0.00001$). Disproportionately large increases in incidence rates were observed in the oldest patient groups.

Conclusions: Atlas fractures occur in older patients and are often associated with concomitant injuries to the head and spine. These types of fractures are increasing in the US, especially among the elderly. The annual incidence increased nearly 700% over the course of the study period and in 2020 was over 13 per million overall. In elderly patients >80 years old, the most recent annual incidence rate was over 157 per million.

Keywords: Atlas, fracture, cervical spine injury, epidemiology, trauma

INTRODUCTION

Cervical spine injuries are becoming increasingly more common and continue to place a significant burden on patients and health-care systems.[1] A substantial proportion of all cervical trauma involves the upper cervical region,[2] and such injuries can result in a great deal of morbidity and mortality.[3,4] Fractures of the C1 vertebra (atlas) frequently result from falls and other traumatic mechanisms leading to hyperextension or axial compression of the cervical spine.[5] Atlas fractures have generally been described as occurring with a bimodal age distribution affecting young adults and the elderly.[6] Elderly patients are particularly susceptible to these injuries due to age-related factors including degenerative

Joseph Gabriel Lyons, Humza Moghis Mian
Department of Orthopaedic Surgery, Wright State University Boonshoft School of Medicine, OH, USA

Address for correspondence: Dr. Joseph Gabriel Lyons, 30 E Apple St Ste 2200, Dayton, OH 45409-2932, USA.
E-mail: joseph.g.lyons@wright.edu

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changes and reduced mobility of the lower cervical spine combined with frequent falls, and the elderly have been shown to sustain atlas fractures at high rates.[3] With an aging and more active population and with the number of people in the oldest age groups expected to continue to grow substantially,[7] it is expected that the number of patients sustaining atlas fractures is rising and will continue to do so.

Despite being a relatively common injury, there is a scarcity of literature regarding the incidence of atlas fractures in large populations. Much of the prior work is limited by small numbers of patients or is outdated.[2,3,8,9] Furthermore, the recent investigations in this area have focused primarily on European patient populations,[6,10,11] which may not be representative of the patient populations in other countries. Matthiessen and Robinson[6] recently documented the epidemiology of atlas fractures in Sweden using a national registry and found that the annual incidence more than doubled over the course of the 15-year study period from 1997 to 2011. It was noted, however, that the sociodemographic context of Sweden and factors unique to its population may limit the translation of those findings to patients from other nations.[6] Additional studies examining other populations, therefore, may improve the scientific knowledge regarding the epidemiology of atlas fractures.

There are currently no up-to-date, population-based epidemiological studies describing the incidence and demographics of atlas fractures in the United States (US) population. The purpose of this descriptive epidemiology study, therefore, was to investigate the incidence and define the demographic characteristics of patients with fractures of the atlas in the US over the last 20 years using a nationally representative sample.

MATERIALS AND METHODS

Data source

The National Electronic Injury Surveillance System (NEISS) is operated by the US Consumer Product Safety Commission (CPSC), which gathers consumer product-related injuries data from approximately 100 hospital emergency departments (EDs) selected as a probability sample of all EDs in the US and its territories.[12,13] NEISS data provide a nationally representative sample of US EDs from which nationwide estimates of the number of injuries associated with (but not necessarily caused by) specific consumer products can be made.[14] Data variables are collected by trained coders at each NEISS hospital and include basic demographic information, injury diagnoses, and a brief narrative description of the incident.[12,14] NEISS data have been widely used to describe and analyze various injuries and those associated with specific activities.[15-17] Due to the publicly available and de-identified nature of the dataset, this study was deemed exempt from institutional review board approval.

Case selection

Cases from the 20-year period from 2001 to 2020 were considered for selection. To isolate all potential acute cervical spine fractures, the NEISS database was queried for all neck (code 89) injuries diagnosed with a fracture (code 57). The initial query resulted in $n = 9392$ unweighted cases of ED visits related to fracture (s) of the cervical spine.

From these records, computer-assisted and manual review of the injury narratives was used to select only those cases with a clear diagnosis of an acute atlas fracture. First, potential cases were identified with a computer-assisted search of the narrative text field for the following case-insensitive strings: "C1" or "1st" or "ATLAS" or "C-1" or "ONE" or "FIRST" or "JEFF" ($n = 1385$ unweighted cases). Each narrative was then manually reviewed to identify only those cases with a clear diagnosis of an atlas fracture. Cases without a clear diagnosis (including any "rule out," "possible," "suspected," or "probable" diagnosis) and cases describing an alternate diagnosis were excluded. Alternate diagnoses which were excluded were those describing cervical fractures, not including C1, cervical strains/sprains, cervical subluxation, and old/chronic fractures. After exclusions, $n = 990$ unweighted cases of atlas fractures were identified for the analysis.

To capture all possible atlas fractures, the same selection procedure was carried out on the entire NEISS 2001–2020 dataset without first specifying the body part and diagnosis code. This is because a maximum of 1 (before 2019) or 2 (2019 and beyond) body part (s) and diagnosis code (s) can be coded for each case. In a case involving multiple diagnoses, only the one (or two, for years 2019 and beyond) which seems to be the most severe is coded, and any other injury diagnoses are listed in the narrative.[18] In addition, its possible that a case could be coded using the diagnosis code "other/not stated" (code 71). This procedure identified an additional $n = 147$ unweighted cases for inclusion in the analysis ($n = 141$ cases coded with a different body part or diagnosis code, $n = 6$ cases with the diagnosis code 71). In total, these criteria resulted in the selection of $n = 1137$ unweighted cases of atlas fractures over the entire study period. Each NEISS database record carries a weighting factor which allows for the conversion of cases (unweighted records) to national estimates (weighted estimates) by accounting for the NEISS stratified probability sampling design. Results,

therefore, include the number of unweighted cases as well as the national total case numbers which are estimated from the sum of individual case weights. In total, the 1137 unweighted cases identified corresponded to a national estimate of 38,092 cases of atlas fractures (95% confidence interval [CI] = 28,337–47,846) occurring in the US over the 20-year period from 2001 to 2020.

Variables

Certain variables were created or regrouped from the NEISS data as follows.

Injury mechanism

Each case narrative was used to assign an injury mechanism. Mechanism of injury was classified as either (1) low energy fall/impact, (2) high energy fall/impact, (3) sports-or exercise-related, or (4) motor/powered vehicle crash. Each case was assigned a single injury mechanism. A low energy fall was defined to be any fall from a height of <6 feet, while a high energy fall was defined as any fall occurring from a height over 6 feet. If this could not be distinguished from the narrative, the injury was considered a low energy fall. Of note, a large number of cases involved falls down stairs/steps. In these instances, any fall down 10 or more stairs/steps was considered to be a high energy fall/impact, while any fall involving <10 steps (or any fall in which the number of steps was not specified) was classified as a low energy fall/impact. Motor/powered vehicle crash included injury mechanisms involving motor vehicles, motorcycles, and powered all-terrain/off-road vehicles.

Disposition from the emergency departments

Disposition from the ED was regrouped into three categories: (1) released, (2) admitted, and (3) fatality.

Location of injury

Location of injury was regrouped into: (1) home, (2) street or highway, (3) school or recreational sports, and (4) other public property.

Associated injuries

Case narratives were individually reviewed for any additional injury diagnoses other than the C1 fracture. As noted above, a maximum of either one or two diagnosis codes can be entered for a single case, and any additional diagnoses are listed in the narrative. Vague symptoms (such as pain), noninjury diagnoses (such as unrelated illness or preexisting conditions), and minor injuries (such as strains/sprains, abrasions, etc.) were not included.

Associated injuries which were recorded were head injuries (including closed head injury, concussion, traumatic brain injury, and intracranial hemorrhage), blunt cerebrovascular injuries (BCVI; includes blunt force injury to the cervical carotid and/or vertebral arteries), chest injuries (including rib and/or sternal fracture, pulmonary and/or cardiac contusion, hemothorax, and pneumothorax), internal organ injuries (including solid intraabdominal organ injury), spinal cord injury, fractures, and lacerations. Associated fractures were further categorized into appendicular fractures (including upper extremity/shoulder girdle and lower extremity/pelvic girdle fractures), spine fractures, and head fractures (including skull and facial fractures).

Race

Race categories in the NEISS dataset include "Not Specified," "White," "Black/African American," "Other," "Asian," "American Indian/Alaska Native," and "Native Hawaiian/Pacific Islander." Due to the small number of cases coded with the latter two race categories, these were combined with the "Other" race category, which is coded when either the ED record indicates more than one race (e.g., multiracial, biracial), or when the race stated in the ED record does not fall into any of the other categories.

Analysis

Statistical analyses were performed using the survey data commands (*svyset*) in Stata/IC, version 15.1 (StataCorp, College Station, TX, US), accounting for sample weights and the complex survey design. Results are reported as numbers of unweighted cases and/or as weighted national estimates with corresponding 95% CIs. The US Census Bureau population estimates were utilized to calculate at-risk person-years during the study period.[19] Incidence rates are expressed as the number of injuries per million at-risk person-years and are calculated as the number of estimated injuries divided by at-risk person-years. Patients were divided into 10-year age groups for age- and gender-specific comparisons of atlas fracture numbers and incidence rates. For additional age-related comparisons of patient demographics, injury characteristics and temporal trends in incidence rates, patients were split into four different age groups (pediatric, <18 years of age; young adult, 18–64 years of age; older age, 65–79 years of age; 80 and over, 80 + years of age). Temporal trends in annual incidence rates over the course of the study period were assessed with Joinpoint regression analyses (Joinpoint Regression Program, Version 4.8.01– April 2020; Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute).[20] Annual percent change (APC) estimates are presented to indicate the magnitude and direction of trends in injury rates for each segment or period as determined by Joinpoint regressions. Student's *t*-test/analysis of variance and

design-adjusted Rao-Scott Chi-square analysis were used for direct comparisons of means for continuous variables and proportions for categorical variables, respectively.[21,22] Of note, CPSC considers a national estimate unstable and potentially unreliable when the number of cases used is <20 or when the estimate is <1200.[23] These numbers, therefore, should be interpreted with caution.

RESULTS

A total of 9539 unweighted records of ED visits related to cervical spine fracture (s) were identified during the 20-year study period from 2001 to 2020, representing a national estimate of 344,208 cases (95% CI = 281,337–407,079) which occurred in an at-risk population of 6,183,899,410 person-years. This corresponded to an overall cervical fracture incidence rate of 55.7 (95% CI = 45.5–65.8) per million person-years in the US. Of all patients with cervical spine fracture (s), a fracture of the atlas was diagnosed in 11.1% of cases. There were an estimated 38,092 atlas fractures (95% CI = 28,337–47,846; 1,137 unweighted cases) during the study period, corresponding to an overall incidence rate of 6.2 (95% CI = 4.6–7.7). When comparing patients who had cervical fracture (s) not involving the atlas with patients who had atlas fractures, the patients with atlas fractures were older, more likely to be female, and slightly more likely to require hospital admission [Table 1].

Among the total of 38,092 atlas fractures occurring during the study period, slightly more than half (53.5%) of the fractures occurred in females and the mean age was 70.7 years (95% CI = 68.7–72.8; range 2–103 years). Table 2 lists the gender-, age-, and race-specific atlas fracture incidence rates calculated over the 20-year study period. The mean age of female patients sustaining atlas fractures was significantly higher than that of male patients (75.8 years versus 64.9 years, respectively; P = 0.00001). A larger proportion of the total number of atlas fractures in males occurred in younger age groups when compared with that in females (percentage of the total number of atlas fractures which occurred in patients <60 years: Males 31.6%, females 15.3%). Nevertheless, atlas fractures were relatively uncommon in young patients of both genders, and there was a similar fracture distribution affecting older patients with a substantial progressive increase in incidence with age for both males and females [Figure 1]. Overall, a majority (63.8%) of cases occurred in patients over the age of 70 years. In both male and female patients, the largest total number of atlas fractures occurred in the 80–89 years age group (male, national estimate: 4025; 95% CI = 2512–5538. female, national estimate: 6718; 95% CI = 4597–8839) and the age group with the highest incidence rate was 90 + years (male, 126; 95% CI = 71–181. female, 139; 95% CI = 92–187). Overall gender- and age-specific atlas fracture incidence rates are shown in Figure 1.

Table 1: Comparisons of patients with atlas fractures versus other cervical spine fractures

	Atlas fracture	Other cervical spine fracture (s)*	*P*
Unweighted cases	1137	8402	
National estimate	38,092	306,117	
Mean age (years)	70.7	64.3	0.00001
Gender (female/male) (%)	53.5/46.5	46.7/53.3	0.0005
Hospital admission (%)	79.5	75.2	0.0319

*Includes cases of cervical spine fracture (s) involving level (s) other than C1

Table 2: Overall and gender, age, and race-specific atlas fracture incidence rates calculated over the entire study period (expressed per million at-risk person-years)

	Incidence rate (95% CI)
Overall	6.2 (4.6-7.7)
Gender	
Female	6.5 (4.8-8.2)
Male	5.8 (4.2-7.4)
Age (years)	
0-9	0.4 (0.1-0.7)*
10-19	1.2 (0.5-1.9)*
20-29	1.9 (1.1-2.7)
30-39	1 (0.5-1.5)*
40-49	2.3 (1.4-3.2)
50-59	3.7 (2.4-5)
60-69	8.6 (6.1-1.1)
70-79	21.9 (15.7-28.1)
80-89	57.9 (40.2-75.6)
90+	135.4 (94.9-175.8)
Race	
White	5.7 (4-7.3)
Black/African American	1.9 (1.1-2.7)
Other	1.9 (0.6-3.3)*
Asian	1 (0.1-2)*

*An estimate which is unstable and potentially unreliable due to the small number of cases. CI - Confidence interval

Race was specified in 78.3% of cases. White patients accounted for an estimated 27,538 atlas fractures (72.3%), representing the largest proportion of patients, followed by African American patients (1550 fractures, 4.1%). The most common mechanisms of injury overall were low energy fall/impact (73.9%), high energy fall/impact (12.8%), and sports- or exercise-related (8.9%). Injury mechanisms differed with age [Table 3]. The most common locations of injury were home (58.1%), unknown/unspecified (17.7%), public property (15.3%), and place of school or recreational sports (6.3%). A large majority of patients (79.5%) were admitted to the hospital, while 20.3% were released from

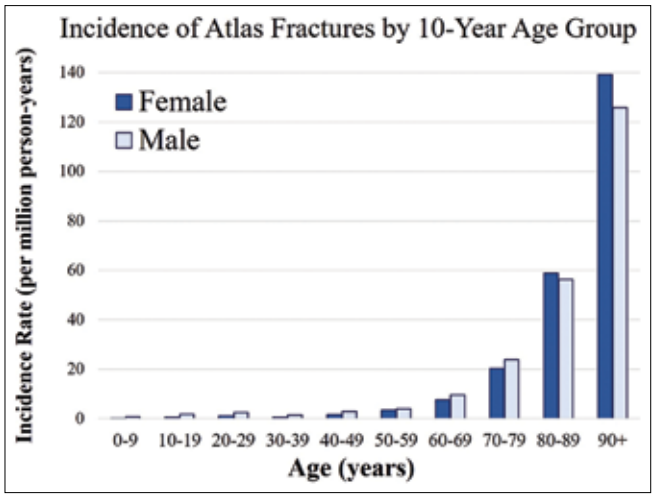

Figure 1: Overall incidence rates of atlas fractures in the United States from 2001 to 2020, by gender and age group

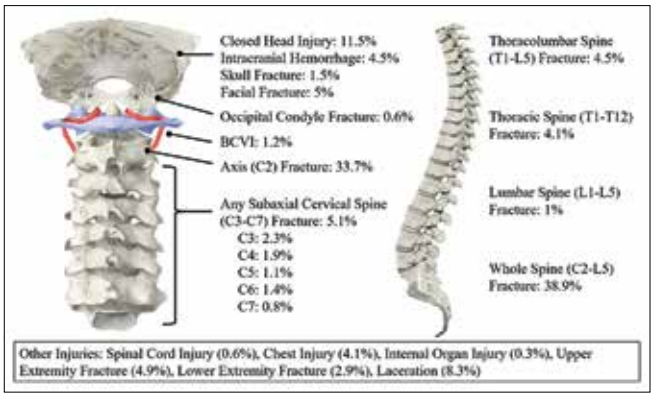

Figure 2: Concomitant injuries of the head and spine, as the percentage of all patients with atlas fractures who sustained the injury. BVCI: Blunt cerebrovascular injury

the ED and 0.2% expired in the ED or after admission. There were no differences in disposition status with age [Table 3].

Overall, only 41.9% of atlas fractures were isolated injuries, with 58.1% of patients sustaining at least one associated injury and 48.2% of patients sustaining at least one additional fracture. Although a larger percentage of older patients had other injuries, the differences weren't statistically significant [$P = 0.2523$, Table 3]. Concomitant injuries of the head and spine were common [Figure 2]. A fracture of C2 was the most common concomitant fracture, and this injury occurred with greater frequency among older patients. Age-related differences in associated injuries and other variables are shown in Table 3. The neurologic injury was rare, occurring in 0.6% of cases.

The annual number of atlas fractures increased over the course of the study period. Increased numbers of atlas fractures were observed in both younger and older adult age groups, while the numbers remained low in the pediatric population. Accounting for population growth yielded a significantly increasing incidence from 1.7 (95% CI = 0.5–2.9) in 2001 to 13.4 (95% CI = 8.7–18) in 2020 (APC = 11, $P < 0.00001$). Temporal trends in annual incidence rates are illustrated in Figure 3. Stratified by gender, the annual incidence of atlas fractures increased significantly for both males (APC = 8.8, $P = 0.000039$) and females (APC = 12.6, $P < 0.00001$). Although the annual incidence increased at a relatively higher rate over the course of the study in females when compared with males, the difference in APC was not statistically significant ($P = 0.1$). Stratified by age group, annual incidence remained relatively constant over the course of the study period in pediatric patients (APC = 2.1, $P = 0.61$), while statistically significant increases in annual incidence rates were observed in young adults 19–64 years of age (APC = 13.9, $P = 0.028$), older-aged adults 65–79 years of age (APC = 8.6, $P = 0.0001$), and patients 80 + years of age (APC = 24.8, $P = 0.008$). The largest increases in atlas fracture incidence rates over the course of the study period were observed among the oldest patients [Figure 4].

DISCUSSION

The current study presents recent nationwide epidemiologic data on atlas fractures in the US over an observation period of 20 years. Previous work in this area has been mostly limited to relatively small patient cohorts, and large-scale epidemiological studies are scarce.[6] This investigation, which included an estimated 38,092 atlas fractures presenting to US EDs from 2001 to 2020, reinforces many of the findings demonstrated in previous studies regarding the demographic characteristics of patients sustaining these types of fractures, while also highlighting a substantial recent rise in annual incidence, especially among elderly patients.

Overall, atlas fractures accounted for 11.1% of all cervical spine fractures, which is consistent with the higher percentages documented in the recent literature. The early studies of atlas fracture epidemiology, which involved smaller numbers of patients, reported lower figures between 4.7% and 6.6%.[8,24-26] In a more recent, population-based study by Matthiessen and Robinson,[6] fractures of the atlas accounted for 10.6% of all cervical fractures (1,553 atlas fractures/14,700 total cervical fractures). Finally, Passias *et al*.[27] recently analyzed a large US inpatient database and found that atlas fractures were present in 13.7% of cases of cervical spine fractures and that this percentage had increased annually over the course of the study period from 2005 to 2013. Given that the total number of cervical fractures also continues to increase,[27] these trends suggest a disproportionate recent increase in the number of patients sustaining atlas fractures.

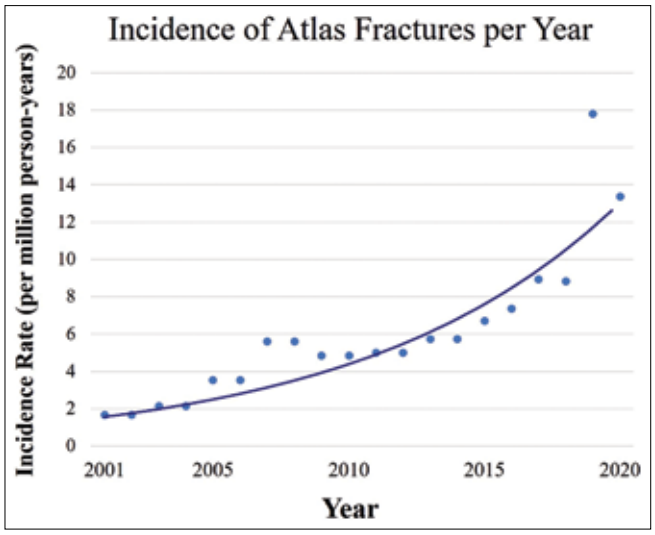

Figure 3: Temporal trends in the annual incidence rates of atlas fractures from 2001 to 2020

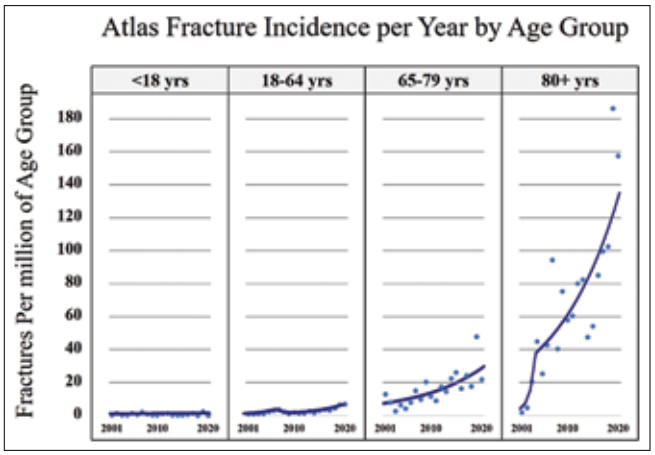

Figure 4: Temporal trends in atlas fracture incidence rates in the United States from 2001 to 2020, by age group

Indeed, Matthiessen and Robinson[6] documented an increasing incidence of atlas fractures in Sweden from 7 per million in 1997 to 17 per million in 2011. The authors also noted that while the incidence in older patients (>50 years) nearly tripled, it remained unchanged in younger age groups (0–49 years). The current study demonstrates similar (although more dramatic) trends in the US population. Expressed per million person-years, the overall atlas fracture incidence rate in the US increased from 1.7 in 2001 to 13.4 in 2020. Stratified by age, incidence rates remained low in patients <65 years of age, and increased substantially in patients >65 years, with greater increases noted in the oldest patients. When comparing the atlas fracture incidence rate during the first 5 years of the study (2001–2005) with that over the last 5 years of the study (2016–2020), the incidence rate had increased 284% in patients aged 65–79 years and 541% in patients aged 80 years and older. Given that increasing age is associated with higher rates of complications and mortality in the context of these injuries,[4,6] it is important to understand the reasons for these trends to inform appropriate preventative efforts. A possible explanation is that the aging and more active US population includes greater numbers of elderly individuals engaging in activities which make them susceptible to falls and subsequently to higher injury rates. In other words, there are more low-energy fractures occurring in a population that is living longer. It is also possible that the increasing incidence simply reflects increasing diagnosis rates. This could be a result of advances in high resolution computed tomography (CT) imaging which have permitted quicker and more accurate diagnoses of spinal injuries, or, in the case of the current study, could be due to increased recognition of atlas fractures by ED physicians. While these are important considerations, the lack of proportional increases in atlas fracture incidence rates in younger patient populations suggests that improved diagnostic rates alone do not account for these trends.

With regard to patient demographic characteristics, the results of the current study are generally consistent with previously published studies of smaller patient populations, although there are some differences. The mean age of patients with atlas fractures has been reported between 49 and 72 years,[3,6,10,11,28] and in the current study was 70.7 years. The mean age of females was higher than that of males, in accordance with the findings of Matthiessen and Robinson,[6] who reported a mean age of 59 years for males and 70 years for females. Although there was a very small peak in incidence rate which occurred between 20 and 30 years in both genders, the relative scarcity of atlas fractures in the younger age groups made this essentially unnoticeable on the fracture distribution curve, which most closely assumed a Type F distribution (unimodal distribution affecting older individuals for both males and females).[29] Unlike a classic Type F fracture distribution, however, the incidence was actually slightly higher in males for all age groups <80 years old, after which the incidence was higher in females. In contrast, atlas fractures have generally been described in the literature as having a Type H fracture distribution (bimodal in both males and females, with a higher male incidence in young patients and a higher female incidence in older patients).[6,30] This discrepancy may be due to changing atlas fracture epidemiology patterns in the US, with more fractures occurring in older patients and less in younger patients. A majority of atlas fractures in elderly patients were the result of low-energy falls, and increased incidence rates in these patients likely reflect an increasing frequency of fragility fractures secondary to improved health and longer life expectancies. In younger patients, on the

Table 3: Age-related differences

	Child (<18 years) (%)	Adult (18-64 years) (%)	Older age (65-79 years) (%)	80 and over (80 + years) (%)	*P*
Unweighted cases	45	309	328	455	
National estimate	1000*	10,053	10,792	16,247	
Incidence rate (95% CI)	0.7 (0.3-1.1)	2.6 (1.8-3.4)	17.1 (12.5-21.7)	71.8 (51.9-91.8)	
Gender (female/male)	22.7*/77.3*	39.7/60.3	50/50	66.2/33.8	0.00001
Race					
Not specified	35.4*	24.7	20	20.1	0.00001
White	44*	66.7	72.5	77.3	
Black	3.5*	6	5.6*	1.9*	
Other	7.1*	1.8*	1.6*	0*	
Asian	10*	0.8*	0.3*	0.7*	
Mechanism of injury					
Low energy	4.4*	42.1	79	94.3	0.00001
High energy	23.3*	24.9	13.4	4.4	
Sports/exercise	53.8	18.6	7.1	1.2*	
Motor vehicle	18.6*	14.4	0.5*	0.1*	
Hospital admission	74.4	76.7	79.8	81.2	0.5445
Any concomitant injury	59.8	52.7	58.6	61	0.2523
Concomitant head injury	20.3*	12.1	11.1	10.9	0.5893
Any concomitant fracture	38.9*	44.4	47.3	51.7	0.305
Concomitant skull/facial fracture	1.5*	9	4.4	6	0.1497
Concomitant spine (C2-L5) fracture	26.2*	33.3	36.1	45.1	0.0131
Combined atlantoaxial (C1 and C2) fracture	24.1*	21.8	31.6	43.1	0.00001
Concomitant subaxial cervical (C3-C7) fracture	0.5*	11.4	5.2	1.5*	0.00001
Concomitant thoracolumbar (T1-L5) fracture	1.7*	8.4	3.8*	2.9*	0.0086
Concomitant extremity fracture	3.1*	7.5	10	6.2	0.3258

*An estimate which is unstable and potentially unreliable due to the small number of cases. CI - Confidence interval

other hand, atlas fractures were most commonly the result of exercise-/sports-related injury mechanisms. Low incidence rates in young patients in the current study, therefore, may in part reflect the effectiveness of several decades of injury prevention efforts in several major sports.[31]

Consistent with previously published findings, concomitant head and spine injuries were commonly associated with atlas fractures,[10,11,25,32] with a concomitant fracture of C2 being the most commonly associated fracture. Combined atlantoaxial (C1-C2) fractures have been reported in 19%–56% of cases of atlas fractures,[6,11,24-26] and in the current study was diagnosed in 33.7% of cases. A fracture of the axis was found more frequently in older patients, in accordance with findings in other populations.[6,11] Finally, neurologic injury associated with a fracture of the atlas was rare, similar to prior reports.[8,24-26,32]

This study has several limitations, many of which are inherent to the NEISS database. Because NEISS data are collected from ED records, cases treated outside the ED such as at urgent care clinics or in outpatient settings, and cases of patients who did not seek medical treatment, aren't captured in the dataset. Thus, the injury rates presented here likely represent conservative estimates. It has previously been suggested that a majority of osteoporotic fractures of the spine are never formally treated by medical professionals because many patients do not seek treatment.[30] If this is the case, the numbers in the current study would likely substantially underestimate the true incidence rates. Unfortunately, its impossible to know what percentage of patients with atlas fractures present for medical care or are treated in an ED setting. Fiedler *et al*.[11] recently reviewed 189 patients with an atlas fracture diagnosed at a European Level 1 trauma center over a 10-year period from 2008 to 2018 and noted that only two patients (1.1%) were treated in an outpatient setting only, suggesting that a large portion of patients with atlas fractures may in fact receive treatment in an ED or inpatient setting. The NEISS database relies on accurate coding and data entry, and the accuracy of the analysis depends on the correctness of the narrative section, which is inherently prone to reporter bias. Furthermore, the system does not allow for individual chart reviews for the accuracy of included cases. Although the NEISS employs rigorous data collection methodologies to minimize misdiagnoses and coding errors,[12,14] the codes alone do not indicate the specific cervical level (s) involved. Making these distinctions, therefore, was dependent upon a manual review of the injury

narratives, which may have resulted in exclusions of cases of atlas fractures which lacked sufficient injury information in the narratives. Finally, there are no radiographic data, precluding analyses based on specific atlas fracture patterns, which have important treatment implications.[5,11] Despite these limitations, the NEISS is a national dataset comprising a heterogeneous patient population with significant external validity, thereby permitting more accurate estimations of injury incidence rates and characterization of general patient demographics than studies involving more limited populations.

CONCLUSION

The findings of the current study indicate that atlas fractures in the US occur primarily in older individuals and often are not isolated injuries. Patient demographics and injury characteristics were generally consistent with previously reported findings in smaller cohorts and in other populations. Furthermore, atlas fracture incidence rates in the US are increasing, especially in the elderly population. Similar trends have previously been documented in Europe. As the elderly population continues to grow both in the US and worldwide, it's likely that the national and global atlas fracture burden will increase accordingly.

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Conflicts of interest

There are no conflicts of interest.

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