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ORIGINAL ARTICLE

Incidence of cervical spine fractures on CT: a study in a large level I trauma center

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Abstract

Introduction/purpose Though spinal fractures constitute a minority of all traumas, the financial burden imposed is immense especially following cervical spine trauma. There have been several papers in the past describing the incidence of cervical spine fractures. In this paper, we report the incidence of cervical spine fractures and correlate with demographic information and cause of injury and review the mechanism of fractures.

Materials and methods We performed retrospective analysis of 934 patients who had undergone CT scan for cervical spine trauma at our institute which includes 16 hospitals and one level I trauma center over a period of 2 years. This list was created from a wider database of 13,512 patients imaged for suspected cervical spine injury. All patients who had at least one positive finding on CT were included in this study irrespective of any demographic difference. Each patient was analyzed by reviewing the medical records, and correlation was sought between demographics and cause of injury.

Results In our study, the peak incidence of cervical spine trauma was in the age group of 21–30 years followed by 31–40 years with a male:female ratio of 2.1. The major cause of injury in the study population was motor vehicle accidents (66.1%), followed by fall from height of less than 8 ft (12.2%). With regard to the ethnic distribution, Caucasians (46.9%) constituted the major population followed by Hispanic population (23.3%). C1 and C2 were observed to be more frequently fractured as compared with the subaxial spine. Incidence of C2 fractures (188 levels) was higher as compared with C1 (102 levels). Incidence of body and lateral mass fractures was marginally higher as compared with odontoid fractures. C7 (50 levels) was the most fractured vertebral body in the subaxial spine followed by C6 (35 levels) and C5.

Conclusion Spinal trauma is on the rise and it helps to know the factors which can guide us for better management of these patients. We can utilize these results to prognosticate and streamline clinical management of these patients.

Keywords Cervical spine fractures · Incidence and cause of fractures · Level of fractures

Introduction/purpose

Spinal fractures constitute a minority of all traumas accounting for approximately 3% of trauma [1–3]. However, the financial burden imposed is immense especially following cervical spine fractures [4, 5]. There is a steady increase in the incidence of trauma and subsequent cervical spine fractures [2]. Knowledge about the spectrum of cervical spine fractures can help emergency physicians to make daily clinical decisions more confidently, build specific treatment protocols, utilize imaging resources effectively, and prognosticate accurately. Early recognition of the injuries and timely intervention in these patients can prevent significant future disability. Over the years, there have been several papers describing the incidence of cervical spine fractures in different regions of the world [2, 6–9]. In this paper, we aim to study the incidence of cervical spine fractures (CSF) and demonstrate a correlation between various demographics and cause of

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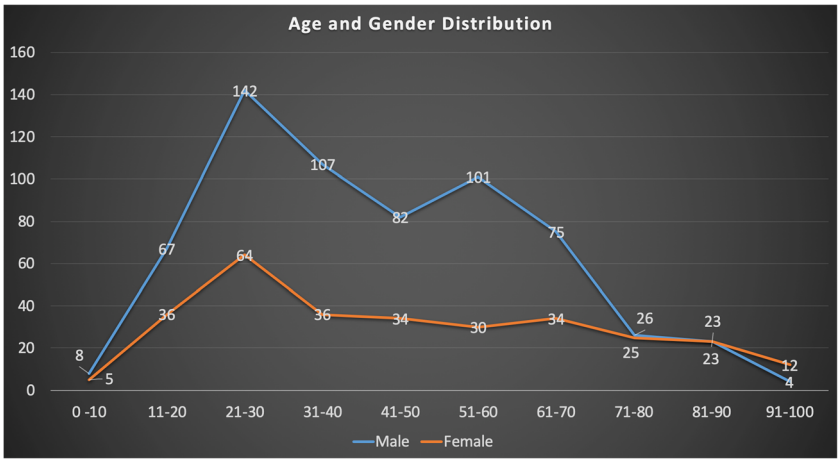

Fig. 1 Age and gender distribution in cervical spine trauma patients

injury (motor vehicle accidents, falls, violence, or sports-related injury) with imaging features of the fractures.

Materials and methods

We performed a retrospective analysis of 934 patients who had undergone CT scan for cervical spine trauma at our institute which includes 16 hospitals and one level I trauma center over a period of 2 years. This list was created from a wider database of 13,512 patients imaged for suspected cervical spine injury. The study was preapproved by the IRB and compliant to the HIPAA guidelines. Individual consents from the patients were not obtained due to the retrospective nature of the study. All patients who had at least one positive finding on CT were included in this study irrespective of any demographic difference. Each patient was analyzed by reviewing the medical records, and correlation was sought between demographic and the imaging features.

Results

Age and gender distribution

A total of 13,512 patients were enrolled for evaluation of traumatic cervical spine injury. Out of these, 934 patients (6.91%) had findings suggestive of injury on CT. These 934 enrolled patients ranged from a 2-month-old male to 96-year-old female (Fig. 1). The mean age of enrolled patients in our study was 43.8 years. One hundred forty-one patients belonged to the pediatric age group (≤ 21 years [10]), and 182 patients fell into the geriatric age group (≥ 65 years [11]). Age groups 21–30 and 51–60 years were the most affected age groups. The extremes of the ages were least affected.

Ethnic distribution

The most enrolled ethnic group in our study was Caucasians accounting for almost half of the total population (47%) (Fig. 2). The other half of study population was contributed

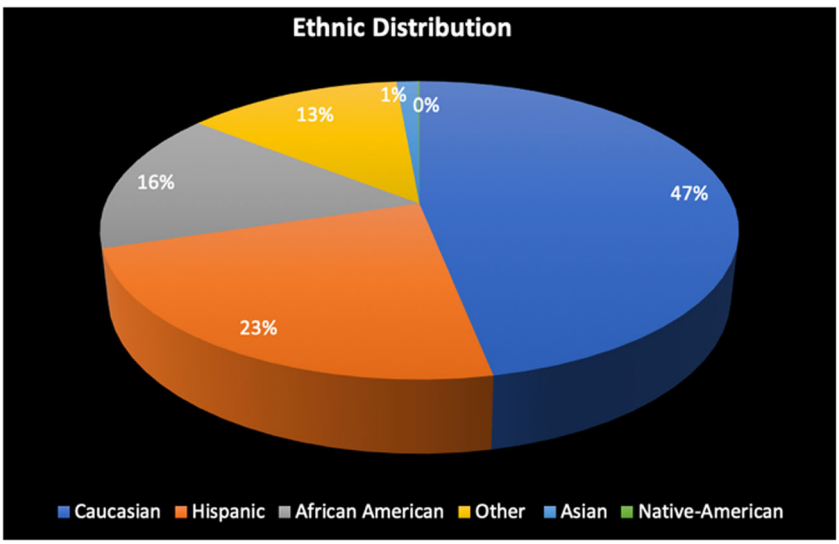

Fig. 2 Ethnic distribution in our study population

by Hispanics (23%), African American (15.4%), others (13%), Asians (1.3%), and Native Americans (0.1%). Hence, overall, Native Americans and Asians were the least affected ethnic groups. Please note that "others" constituted ethnic groups that did not qualify into the conventional groups and the ones whose ethnicity was not revealed.

Cause of spine trauma

Based on the literature review and analysis of our dataset, several defined groups were created describing the cause of injury. This included motor vehicle accidents (MVA), fall from a height of greater than or less than 8 ft (FH > or < 8 ft), automobile pedestrian accidents, violence, and sports injuries. The cut-off of 8 ft was arbitrarily used to divide serious falls from the relatively trivial ones. Figure 3 shows the overall distribution of different causes of CSF in the entire study population. Overall MVAs were the most common cause of cervical spine fractures (CSF) detected on CT accounting for 66% of all causes. The 663 patients categorized as MVAs included car crashes, motorcycle crashes, and all-terrain vehicle (ATV) accidents (14 patients). Specific role (driver or passenger) of the patients in the accidents was not identified. Most crashes involved other motor vehicles and some involved static objects. Patients who got ejected from the vehicle during the accident and got injured were also included in this group. FH < 8 ft, FH > 8 ft, automobile pedestrian accidents, violence, and sports-related injuries account for the rest of the 34%. FH < 8 ft was the second most frequent cause of cervical spine injury. Most of the falls in these patients were attributed to a secondary medical condition, e.g., stroke, seizure, arrhythmia, and syncope, and were from standing height and hence were relatively low-velocity injuries. The FH > 8 ft group included patients who fell from a horse, staircase, roof, and buildings during construction. Forty-four patients who were categorized into violence group included patients who were assaulted or were victims of gunshot (16 patients), explosion, or electrocuted. Sports-related injuries were the least common with only 6 patients suffering from CSF.

Stratification of the cause of injury according to age showed that MVA was the most common cause in patients ranging from 0 to 80 years and FH < 8 ft being the second most common cause (Table 1). In age groups of 81–90 and 91–100 years, the most frequent cause was FH < 8 ft height followed by MVAs. Injuries related to violence and sports were common in the age groups ranging from 11 to 50 years.

Cause of spinal trauma in pediatric and geriatric population

Among the 141 pediatric patients (< 21 years), the prime cause of CSF was MVA followed by pedestrian accidents (Fig. 4). Similarly, out of the 182 geriatric patients (> 65 years), the most prevalent cause of CSF was MVA followed by FH < 8 ft (Fig. 5).

Anatomical distribution

We divided the CSF into vertebral "body" and vertebral "process" fractures and noted the level of injuries. Vertebral "process" fractures included the fractures of pedicle, transverse fracture, lamina, or spinous process. Figure 6 shows an overview of the distribution of CSF in our study. Two hundred forty-five patients had 290 vertebral "body" fractures involving the axial spine (C1 and C2) while 130 patients had 150 vertebral "body" fractures involving the subaxial spine (C3 through C7). The most frequently fractured vertebral body was C2 (188 fractures), followed by C1 (102 fractures), C7 (50 fractures), and C6 (34 fractures) irrespective of the cause of injury (Fig. 7). Out of the total 188 fractures involving C2, 91 fractures involved the odontoid process while 97 fractures involved rest of the C2.

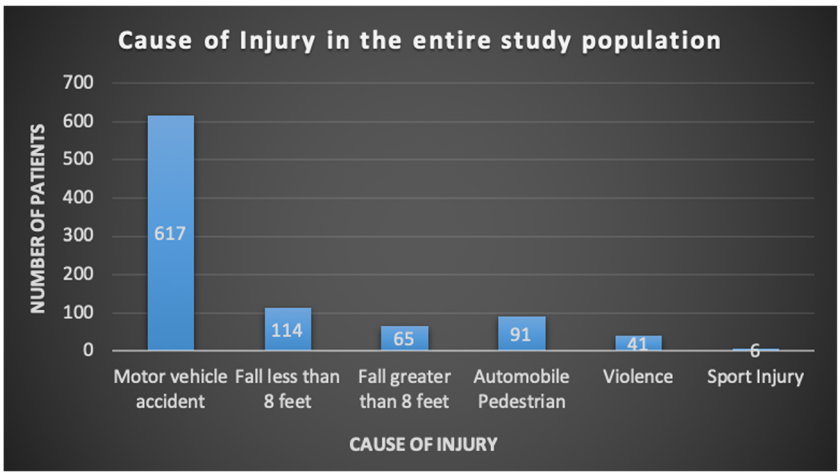

Fig. 3 Cause of injury in the entire study population

Table 1 Age-stratified causes of injury

Age	Cause of injury						
	MVA	Fall less than 8 ft	Fall greater than 8 ft	Automobile-pedestrian	Violence	Sports injury	Total
0–10	7	1	0	4	1	0	13
11–20	75	3	2	14	8	1	103
21–30	159	3	8	23	12	1	206
31–40	106	9	7	13	7	1	143
41–50	82	8	10	9	5	2	116
51–60	76	15	20	14	5	1	131
61–70	69	15	14	9	2	0	109
71–80	24	21	2	3	1	0	51
81–90	15	28	2	1	0	0	46
91–100	4	11	0	1	0	0	16
Total	617	114	65	91	41	6	934

Vertebral "process" fractures were much more frequent than "body" fractures. Five hundred two patients had 924 vertebral process fractures. C7 and C6 vertebral processes were the most fractured with a decrease in the number of fractures as one goes from C5 to C1. Transverse process was the most frequently fractured process.

Table 2 demonstrates the relationship between the level of fracture and the cause of injury. Authors did not find any correlation between the cause of injury and level of the fracture.

Discussion

Cervical spine fractures (CSF) constitute 2–3% of all traumas, and there is an increasing trend towards traumatic fractures of cervical spine [1, 2, 12]. The cervical spine injuries range from nonsignificant injuries, i.e., fracture of the spinous process to massive vertebral dislocations causing transection of the spinal cord. Injuries to the spinal cord, cervical vessels, and closed head injuries are the primary cause of severe morbidity and mortality in these groups of patients. Cervical spine has a natural vulnerability to traumatic injuries as compared with thoracic and lumbar spine as it is responsible for bearing the weight of the skull with generous freedom of movement [13, 14]. Whiplash injuries resulting from sudden acceleration-deceleration mechanism are the most common cervical spine injuries [15]. MVAs are responsible for most of these injuries. Subaxial cervical spine serves as a fulcrum between the stiff thoracic spine and relatively mobile and heavy skull. Excessive motion at this level from whiplash injuries leads to severe bony and ligamentous injuries.

Approximately 7 out of 100 patients (6.91%) showed CSF in patients who underwent CT for suspected cervical spine injury. The 21–40-year-old individuals endured most fractures in our study. Studies conducted all over the world have shown that the younger population and more frequently male population in the age group of 20–45 years old are more prone to CSF. This has been

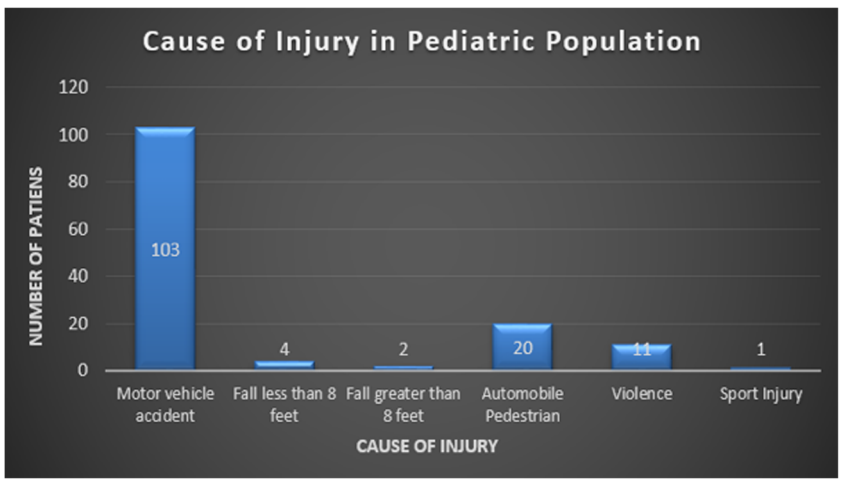

Fig. 4 Cause of injury in the pediatric population

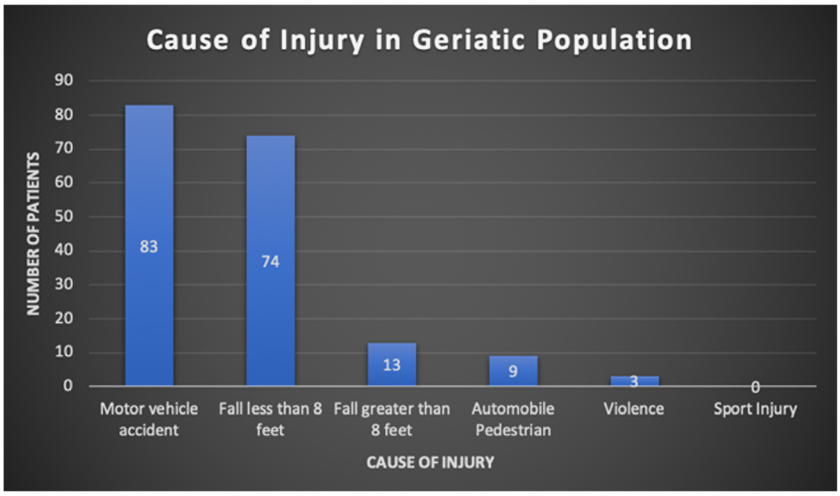

Fig. 5 Cause of injury in the geriatric population

postulated due to their increased involvement in daily life, participation in risky occupational and recreational activities [9]. A similar patient distribution was reported by the NEXUS study group with majority of them falling within 20–40 years [16]. An analysis of 562 patients in Germany reported a mean age of 43.8 years (range 6–100 years), which is surprisingly the same as in our patient population [12]. However, another nationwide survey of cervical spine trauma in the USA conducted by Passias et al. [2] noted a higher average age of 59.13 years with an increasing trend over the years. We postulate that this rising trend is due to increase in the mean age of the Americans over the years [17]. The ethnic distribution of the patients enrolled in this study was representative of distribution of population in our state [18]. Hence, we can deduce that ethnicity has no association with the incidence of CSF.

MVA (66.1%) and FH < 8 ft (12.2%) and FH > 8 ft (7%) alone accounted for 85.3% of all cervical spine trauma detected on CT. We believe that the higher incidence of CSF in MVA and FH > 8 ft is due to its inherent high energy mechanism. It is vital to note that a generalized increasing trend in the incidence of cervical fractures due to falls and violence has been observed in the past few decades [2]. We observed a higher incidence of CSF in elderly patients (> 60 years) with FH < 8 ft relative to pediatric patients. This is clinically important since even trivial injuries can be catastrophic in elderly population in the presence of osteoporosis and severe degenerative changes [19, 20].

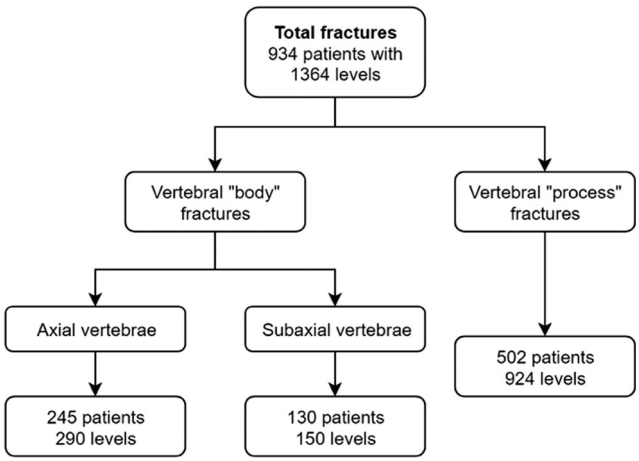

Fig. 6 Overview of the anatomical distribution of cervical spine fractures

MVA is the fourth most common cause of mortality in the USA after cardiac diseases, cancer, and chronic lower respiratory tract infections according to data published by CDC in 2015 [21]. Even though there has been a significant reduction in cervical fractures due to MVAs in the USA since 2005 accounting for 38.8% of all cervical spine injury in 2013, it is still the major contributor [2]. Major trauma studies conducted in Canada, India, China, other Asian countries, Iran, and African subcontinent have shown MVAs to be the most common cause of spine trauma [9, 22–25]. Interestingly, European countries have seen a shift from motor vehicle accident to falls as the most frequent cause of spinal injury attributed to stringent vehicular safety and policy change [7, 12].

It is known that the fractures involving axial cervical spine are far more common than the subaxial spine [26, 27]. We observed a predictable incidence of fractures involving C1 and C2, accounting for two-thirds of all CSF. These injuries often require high forces and are associated with occipital condyle fractures and serious ligamentous injuries resulting in atlanto-occipital and atlanto-axial instability. The proposed explanation for the observed difference in the distribution is the distinctive anatomical and biomechanical interactions at this level. The unique-shaped vertebrae (odontoid process is more prone to fracture), thin rim-like body, high mobility (with rotational movements), articulation with heavy cranium which acts as the lever, and heavy reliance on ligamentous support are some of proposed explanations [28].

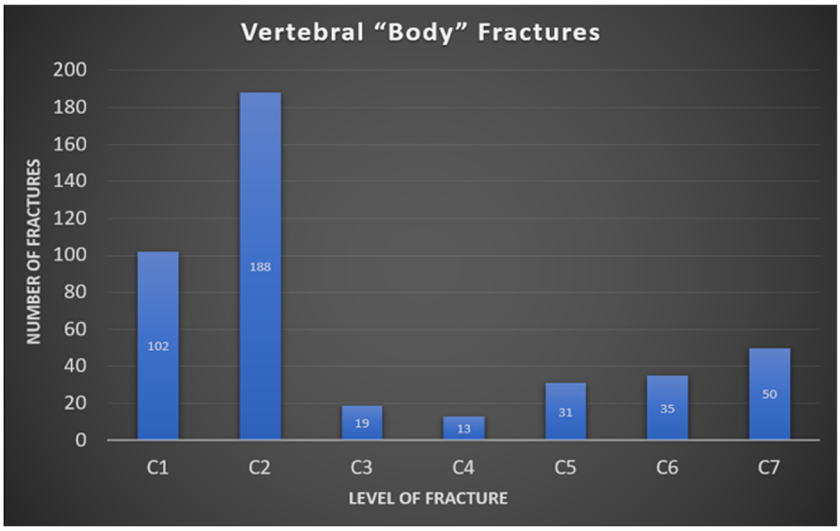

Fig. 7 Incidence of vertebral body fractures

Rest of the one-third fractures involves the subaxial spine with C7 and C6 vertebrae being the most common. Spinous and transverse processes are most often fractured in subaxial cervical spine due to relatively longer and slender vertebral processes easily prone to traction. Disproportionate pull of the muscles attached to the lower cervical spinous processes (like trapezius) against the interspinous and supraspinous ligaments has also been shown to cause fractures of spinous process during sports (golf, volleyball, weight lifting, etc.) [29–31]. A large multicentric study (NEXUS) of trauma patients analyzed a total of 818 patients with radiographic evidence of cervical injury [6]. They observed a similar pattern of distribution with C2 being the most injured vertebra (286 levels) followed by C6 (242 levels), C7 (228 levels), and C1 (105 levels). Several other studies across the globe have consistently reported similar anatomic distribution [2, 7, 9, 12, 32].

There are several limitations that should be considered while interpreting the results of our study. The retrospective nature of the study allows for the inherent bias associated with it. Since ours is a single institutional study, it limits the generalizability of the findings which is crucial when extrapolating the results to a different geographical location. We were not able to study the morphology of fractures (complete or incomplete burst fracture, compression fracture) which could have crucial clinical implications.

In summary, cervical spine fractures have a bimodal age distribution with male preponderance and no ethnic predisposition. Motor vehicle accidents and fall from a height of less than 8 ft are the number one cause of cervical spine fractures in patients below 80 years and above 80 years, respectively. We observed no association between the cause of injury and level of cervical spine fractures. Axial cervical spine fractures are more frequent and should be consciously excluded due to grievous nature of the injury associated with it. Vertebral "process" fractures outnumber vertebral "body" fractures and commonly involve the C6 and C7 vertebrae.

Table 2 Stratified incidence of fractures according to different causes of injury

Cause of injury	Fracture location								
	Axial fractures			Subaxial fractures					
	C1	C2		Body					Vertebral process
		Dens	Other fractures	C3	C4	C5	C6	C7	
Motor vehicle accident	66	60	70	12	8	20	18	32	794
Fall less than 8 ft	21	24	14	3	4	6	7	4	37
Fall greater than 8 ft	2	2	1	1	1	2	2	4	30
Automobile-pedestrian	11	5	9	3	0	1	6	6	44
Violence	1	0	3	0	0	1	2	4	15
Sports injury	1	0	0	0	0	3	0	0	4
Total	102	91	97	19	13	33	35	50	924

Authors' contributions Shekhar Khanpara—collection and analysis of the data and the writing of the paper

Daniel Ruiz Pardo—collection and analysis of the data

Susanna Spence—guidance in analysis of the data and reviewing the paper

O Clark West—guidance in analysis of the data and reviewing the paper

Roy Riascos—conception of the idea and design of the analysis

Compliance with ethical standards

The study was preapproved by the IRB and compliant to the HIPAA guidelines.

Conflict of interest The authors declare that they have no conflict of interest.

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