Comparative Analysis of Characteristics of Lower- and Mid-Cervical Spine Injuries in the Elderly

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Abstract:

Introduction: Elderly patients have a higher frequency of upper cervical fractures caused by minor trauma; nevertheless, the clinical differences between mid- and lower-cervical (C6-C7) injuries are unclear. The aim of this study was to compare the epidemiology of lower- and mid-cervical injuries in the elderly.

Methods: This multicenter, retrospective study included 451 patients aged 65 years or older who had mid- or lower-cervical fractures/dislocations. Patients' demographic and treatment data were examined and compared based on mid- and lower-cervical injuries.

Results: There were 139 patients (31%) with lower-cervical injuries and 312 (69%) with mid-cervical injuries. High-energy trauma (60% vs. 47%, p=0.025) and dislocation (55% vs. 45%, p=0.054) were significantly experienced more often by elderly patients with lower-cervical injuries than by patients with mid-cervical injuries. Although the incidence of key muscle weakness at the C5 to T1 levels were all significantly lower in patients with lower-cervical injuries than those with mid-cervical injuries, impairments at C5 occurred in 49% of them, and at C6, in 65%. No significant differences were found in the rates of death, pneumonia, or tracheostomy requirements, and no significant differences existed in ambulation or ASIA impairment scale grade for patients after 6 months of treatment.

Conclusions: Elderly patients with lower-cervical fractures/dislocations were injured by high-energy trauma significantly more often than patients with mid-cervical injuries. Furthermore, half of the patients with lower-cervical injuries had mid-cervical level neurological deficits with a relatively high rate of respiratory complications.

Keywords:

elderly, cervical spinal cord injury, lower-cervical injury, cervicothoracic injury

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Introduction

Cervical spine injuries in the elderly can be severe and often follow a detrimental course. With the global increase in the elderly population, the incidence of these injuries is also increasing[1]. This trend underscores the need for epidemiological studies and development of injury-specific treatment strategies. Research indicates an epidemiology of cervical spine injuries in the elderly that is distinct from that in younger individuals; moreover, the incidence of upper cervical spine injuries is higher in the elderly than in younger individuals[2]. One example is odontoid fractures in the elderly, which may occur from minor external forces, such as a fall from a standing position[3]. The growing evidence highlights a predominance of upper cervical spine injuries over mid-cervical injuries in the elderly.

However, mid- and lower-cervical injuries have not been comparatively explored. Consequently, the differentiation between mid- and lower-cervical injuries remains uncertain, which raises a clinical question. The mid- and lower-cervical spines have distinct characteristics. For instance, the lower-cervical spine presents radiographic assessment challenges due to the presence of the shoulder, which often results in overlooked injuries[4]. Furthermore, certain lower-cervical injuries are less likely to cause neurological deficits and exhibit a limited range of symptoms[4]. Theoretically, lower-cervical spine injuries should preserve upper extremity function and patient physical capabilities. Some lower-cervical injuries comprise cervicothoracic junctional injuries, which present significant clinical issues regarding treatment and prognosis. The instability due to the anatomical characteristics[5] can result in a distinct clinical course from mid-cervical spine injuries.

As mentioned above, although lower-cervical injuries may exhibit characteristics that are different from those of mid-cervical injuries, epidemiological and clinical research focusing on the level of injury is insufficient. To address this, we carried out a retrospective study using the national multicenter study database of cervical spine and cervical spinal cord injuries in elderly individuals (65 years and older)[6]. Our clinical questions were how often lower-cervical injuries in elderly patients are overlooked and whether the distribution of neurological deficits and clinical outcomes, including complications, differs from that observed in mid-cervical injuries. To accurately assess patients for prompt trauma diagnosis and treatment, their epidemiological characteristics must be understood. Thus, the objective of the current study was to elucidate the epidemiology of lower-cervical injuries in the elderly, in comparison to mid-cervical injuries.

Materials and Methods

Patient population

This was a multicenter retrospective study using a database of patients aged 65 years or older, hospitalized for cervical spinal cord or cervical spine injuries between 2010 and 2020. This study was carried out by the Japan Association of Spine Surgeons with Ambition group, comprising 33 medical institutions[6]. The minimum follow-up period was 3 months. The study protocol was approved by each of the 25 representative institutions' institutional review boards. Con-

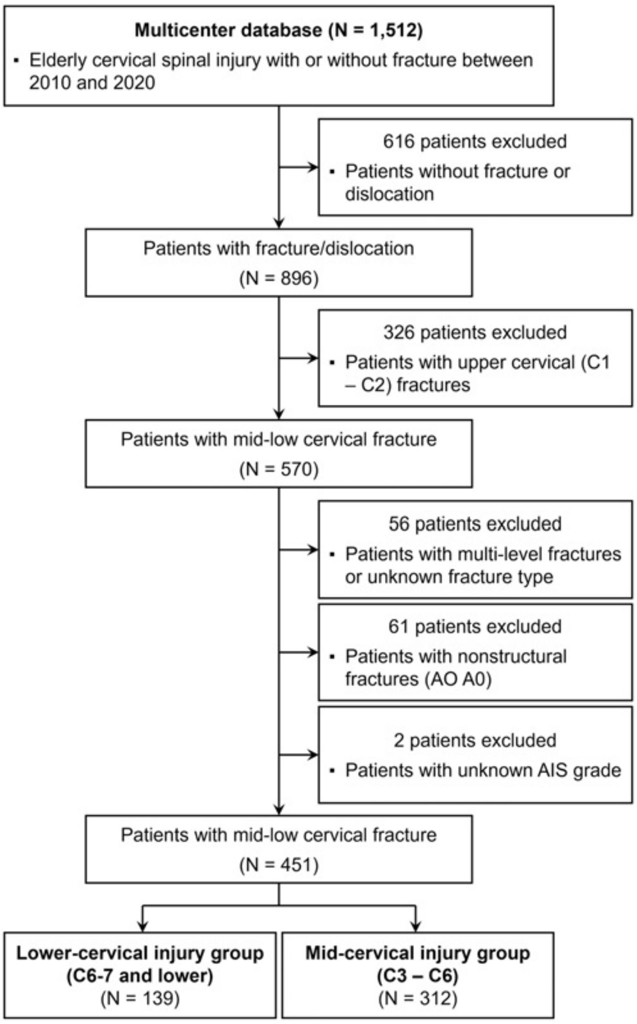

Figure 1. Patient selection flowchart.
AO, AO (Arbeitsgemeinschaft für Osteosynthesefragen) Spine classification; AIS, ASIA (American Spinal Injury Association) impairment scale.

Table 1. Injury Levels.

	Lower N=139	Mid N=312
C3		16 (5.1%)
C3–C4		17 (5.4%)
C4		26 (8.3%)
C4–C5		44 (14%)
C5		50 (16%)
C5–C6		82 (26%)
C6		77 (25%)
C6–C7	75 (54%)	
C7	51 (37%)	
C7–T1	13 (9.4%)	

sidering the retrospective nature of the study, the requirement for informed consent was waived. The study's opt out option was posted on https://web.sapmed.ac.jp/orsurg/guide/hj0g2h00000007ax-att/pgsps60000000g3l.pdf; no inquiries were received.

There were 1,512 patients in the dataset. Of these, 896 patients had fractures and/or dislocations. We excluded 326 patients with upper cervical (C1-C2) injuries, 2 with multi-level fractures, 54 with unclear injury classification, 61 with nonstructural injuries (AOSpine classification A0), and 2 with unknown ASIA impairment scale (AIS) grade at the time of injury. Finally, only 451 patients were analyzed (Fig. 1).

Lower-cervical spine injury

We defined lower-cervical injuries as injuries at the C6-C7 level (between C6 and C7) or more caudal levels. For example, C6 vertebral fractures are mid-cervical injuries, while C6 dislocations are lower-cervical injuries because they involve C6 and C7. Injuries below T1 were not included because the dataset included only cervical spine injuries. Therefore, lower-cervical spine injuries included C6-7, C7, and C7-T1 injuries (Table 1).

Patients' demographic and operative data

We recorded age, sex, comorbidities, ambulation before injury, cause of injury, and diagnostic delay. Injury causes were categorized as having resulted from falling down on a level surface, high-energy trauma (high fall and traffic accidents), and others. We also recorded dislocation, ossification of the posterior/anterior longitudinal ligament (OPLL/OALL), type of motor paralysis (tetraplegia or central cord syndrome), AIS, and paralysis of each key muscle grading as manual muscle testing (MMT). We defined muscle weakness as MMT of <4 and compared patients' MMT levels between injury onset and 6 months later. We also investigated fracture types based on the AOSpine classification and the range of increased signal intensity (ISI)[7] in T2-weighted images on magnetic resonance imaging (MRI). Moreover, we determined whether surgery was carried out, perioperative and postoperative complications during hospitalization, and ambulatory ability, as well as AIS at 6 months after injury.

Statistical analysis

Data are presented as means±standard deviations for continuous variables and as numbers and percentages for categorical data. Statistical analyses were performed using R version 4.2.2 (http://www.R-project.org) for the Wilcoxon rank sum test, Fisher's exact test, and Pearson's Chi-squared test. A $p<0.05$ was considered a significant difference.

Results

There were 139 patients (31%) with lower-cervical injuries, which was less than half of the patients with mid-cervical injuries at 312 (69%). There were no significant differences in age or sex. The lower-cervical injuries were significantly more often caused by high-energy trauma (60% vs. 47%, p=0.025), and dislocation (55% vs. 45%, p=0.054) was more common in patients with lower-cervical injuries. There was no statistically significant difference in diagnostic

Table 2. Demographics.

	Lower N=139	Mid N=312	*p*-value
Age, years	75.6±6.8	75.3±6.4	0.57
Sex, male	101 (73%)	227 (73%)	0.98
Cause of injury			**0.025**
High-energy trauma	83 (60%)	146 (47%)	
Falling down	52 (37%)	146 (47%)	
Others	4 (3%)	20 (6%)	
Diagnostic delay	16 (12%)	24 (8%)	0.19
OPLL	28 (20%)	56 (18%)	0.58
OALL	32 (23%)	75 (24%)	0.81
Dislocation	76 (55%)	140 (45%)	0.054
AOSpine classification			0.056
A	28 (20%)	89 (29%)	
B	39 (28%)	97 (31%)	
C	72 (52%)	126 (40%)	
AOSpine classification (facet)			0.44
F1	7 (5%)	10 (3%)	
F2	9 (6%)	18 (6%)	
F3	3 (2%)	14 (4%)	
F4	12 (9%)	39 (12%)	
No	108 (78%)	231 (74%)	
SCI			0.86
Tetraplegia	56 (40%)	124 (40%)	
Central cord syndrome	25 (18%)	63 (20%)	
No	58 (42%)	125 (40%)	
AIS			0.53
A	22 (16%)	53 (17%)	
B	8 (6%)	19 (6%)	
C	17 (12%)	55 (18%)	
D	34 (24%)	60 (19%)	
E	58 (42%)	125 (40%)	
ISI upper expansion			0.055
2 levels≤	12 (18%)	18 (11%)	
1 level	27 (40%)	51 (31%)	
Fracture level	28 (42%)	98 (59%)	
Unknown	72	145	

OPLL, ossification of the posterior longitudinal ligament; OALL, ossification of the anterior longitudinal ligament; AOSpine, AO (Arbeitsgemeinschaft für Osteosynthesefragen) Spine; SCI, spinal cord injury; AIS, ASIA (American Spinal Injury Association) impairment scale; ISI, increased signal intensity on magnetic resonance imaging

delay (12% vs. 8%, p=0.19). Neurologic deficits were similar in both groups, with approximately 40% suffering tetraplegia and 20% suffering central cord syndrome; AIS grades were also not significantly different (Table 2).

ISI, which indicates spinal cord damage on MRI, remained at the fracture level in 42% and 59% of patients with lower- and mid-cervical injuries, respectively. Patients with ISI expanding above the fracture level were more likely to have lower-cervical injury (p=0.055) (Table 2). The incidence of key muscle weakness at the C5-T1 levels was significantly lower in patients with lower-cervical injuries, although, C5 and C6 impairments occurred in 49% and 65% of the patients with lower-cervical injuries, respectively. Hence, half of the patients with lower-cervical injuries still had mid-cervical level neurological deficits (Table 3).

Both groups required surgical treatment at a high rate (88% vs. 81%, respectively). The posterior approach was predominantly used in both groups, with patients with lower-cervical injuries significantly less likely to be treated with decompression (35% vs. 46%, p=0.047). Although respiratory failure occurred significantly less frequently in patients with lower-cervical injuries than in those with mid-cervical injury (9% vs. 17%, p=0.024), there were no significant differences in the death rates, pneumonia, or tracheostomy requirements. The incidence of deep vein thrombosis (DVT) was significantly higher in patients with lower-cervical injuries (4% vs. 1%, p=0.031). There were no significant differences in AIS grade or ambulatory ability at 6

Table 3. Neurological Deficits.

	Time of injury			6 months after		
	Lower N=80	Mid N=185	*p*-value	Lower N=57	Mid N=144	*p*-value
Muscle weakness (MMT<4)						
C5 (elbow flexor)	20 (25%)	108 (58%)	**<0.001**	4 (7%)	40 (33%)	**<0.001**
C6 (wrist extensor)	31 (39%)	125 (68%)	**<0.001**	7 (12%)	45 (37%)	**<0.001**
C7 (elbow extensor)	33 (41%)	136 (74%)	**<0.001**	6 (11%)	44 (36%)	**<0.001**
C8 (finger flexor)	48 (60%)	141 (76%)	**0.007**	13 (23%)	54 (44%)	**0.006**
T1 (finger abductor)	52 (65%)	142 (77%)	**0.047**	16 (28%)	61 (50%)	**0.006**
L2 (hip flexor)	51 (64%)	114 (62%)	0.74	22 (39%)	38 (31%)	0.33
L3 (knee extensor)	48 (60%)	111 (60%)	>0.99	20 (35%)	38 (31%)	0.60
L4 (ankle dorsiflexor)	47 (59%)	111 (60%)	0.85	20 (35%)	38 (31%)	0.60
L5 (long toe extensor)	48 (60%)	111 (60%)	>0.99	20 (35%)	38 (31%)	0.62
S1 (ankle plantar flexor)	47 (59%)	109 (59%)	0.98	20 (35%)	38 (31%)	0.60

MMT, manual muscle testing

months after injury (Table 4).

Discussion

This study, which defined lower-cervical fractures/dislocations as those below the C6-7 level, found the proportion of high-energy trauma as the cause of lower-cervical injuries in elderly patients was higher than in those with mid-cervical injuries. Although there were significant differences in the C5 to T1 key muscle weakness occurrence rate attributed to the injury level, there were no significant differences in AIS grade. Additionally, 25%-39% of patients with lower-cervical injuries still suffered mid-cervical-level neurological deficits.

Although the population of elderly patients with traumatic spinal cord injuries is increasing globally[1,8-10], these injuries manifest differently in young adults and the elderly[2]. At present, in Japan, 88% of spinal cord injuries involve the cervical spine and the median patient age is 70 years[11]; therefore, we set our study population as an elderly cohort. Several previous studies[12,13] have focused on younger patients who sustained high-energy traumatic injuries; however, mid- and lower-cervical injuries have rarely been comparatively studied. One such epidemiologic study featured a study population with a mean age of 34.4 years, mostly injured as a result of traffic accidents (45%) or falls from heights (40%). Most of these patients' injuries occurred at the C5 level; this was true for both cervical spine and cervical cord injuries[12]. Thus, in young adults with high-energy traumatic injuries, mid-cervical injury appears common. Additionally, a Level 1 pediatric trauma center reported that upper (C1-C4) and lower (C5-C7) injuries accounted for 68% and 25% of their caseload, respectively[13]. Hence, pediatric cervical spinal cord injuries typically occur at higher cervical spine levels. Thus, in the elderly, lower-cervical injuries are more likely to result from high-energy trauma.

Delayed diagnosis of cervical spine injuries in the elderly remains problematic[14]. In fact, cervicothoracic junction injuries can be missed in patients of any age given their poor visibility on standard lateral radiographs[4]. Therefore, there is a valid and pressing concern that lower-cervical spine injuries are being missed in elderly patients. Fortunately, our results suggest that this may not be the case. CT scans are commonly recommended in cases of cervical spine trauma[15], and MRI scans are frequently performed in patients both with and without neurologic deficits[16]. Many of our data set cases underwent both CT and MRI scans. Assuming that many patients undergo both types of scans, we would not expect that there would be similar rates of missed lower- versus mid-cervical injuries. Surprisingly, cervical spine injuries were more frequently missed in the elderly, regardless of level. Although concerns exist over the overuse of cervical spine CT scans in the emergency department[17], rapid imaging is still a necessary and preferred method for diagnosing these injuries in the elderly[18].

Similar numbers of patients with mid-cervical spine reported that their injuries were due to high- or low-energy trauma; however, lower-cervical spine injuries were significantly more likely to be caused by high-energy trauma, and the resultant lower-cervical spine injuries more frequently resulted in dislocations and AOSpine classification type C injuries. Although in the elderly, minor trauma often causes upper cervical spine (C1-C2) injuries[18], high-energy trauma increasingly causes more lower-cervical injuries. Normally, the cervicothoracic junction is stiffer than the cervical spine[19]. In the elderly, degeneration alters the stiffness relationship between the cervical spine and cervicothoracic junction, thereby altering the injury pattern. The mid-cervical spine-between the head and cervicothoracic junction-is normally mobile and therefore subject to high stresses as the head swings following a traumatic impact. Nevertheless, the response of the cervical spine to external forces is altered in the elderly because degeneration reduces the mobility of the mid-cervical spine[20]. This may result not only in an increase in upper cervical injuries[2] but also in stress concentrations at the lower-cervical in high-energy

Table 4. Treatment and Progress.

	Lower N=139	Mid N=312	*p*-value
Surgical treatment	123 (88%)	254 (81%)	0.061
Conversion to surgery	25 (18%)	43 (14%)	0.25
Surgical procedure			0.47
Posterior	110 (90%)	218 (86%)	
Others	5 (4%)	13 (5%)	
Anterior	7 (6%)	23 (9%)	
Others	5 (4%)	13 (5%)	
Decompression	43 (35%)	117 (46%)	**0.047**
Intraoperative complications	2 (1%)	9 (3%)	0.52
Dura tear	1	4	
Neurological	1	3	
VA injury	0	1	
Cardiac arrest due to bleeding	0	1	
Complications	57 (41%)	132 (42%)	0.80
Death	6 (4%)	20 (6%)	0.38
Deep SSI	1 (1%)	4 (1%)	>0.99
Pneumonia	19 (14%)	46 (15%)	0.76
Respiratory failure	12 (9%)	52 (17%)	**0.024**
Tracheostomy	3 (2%)	17 (5%)	0.12
Dysphagia	15 (11%)	45 (14%)	0.29
DVT	5 (4%)	2 (1%)	**0.031**
PE	0 (0%)	1 (0%)	>0.99
Ambulation, 6 months			0.54
Walk w/o assistance	76 (72%)	154 (66%)	
Walk w/ assistance	10 (10%)	30 (13%)	
Nonambulatory	19 (18%)	49 (21%)	
Unknown	34	79	
AIS, 6 months			0.76
A	8 (12%)	15 (10%)	
B	3 (4%)	8 (5%)	
C	9 (13%)	18 (12%)	
D	24 (36%)	66 (45%)	
E	23 (34%)	41 (28%)	
Unknown	72	164	

VA, vertebral artery; SSI, surgical site infection; DVT, deep vein thrombosis; PE, pulmonary embolism; AIS, ASIA (American Spinal Injury Association) impairment scale

trauma due to the long lever arm action of the head and stiffness changes within the cervicothoracic junction area. Thus, examination of cervical trauma in elderly patients, especially those with high-energy traumatic injuries, should include comprehensive cervicothoracic junction imaging.

Differences among various kinds of injuries may have influenced the incidence of DVT in patients with acute spinal cord injury complicated by cervical spine fractures. These patients possess numerous risk factors[21] for DVT occurrence, including trauma, paraplegia, surgery, and bed rest[22]. Trauma contributes to DVT development by inducing a state of systemic hypercoagulability[23]. Because high-energy trauma caused significantly more lower-cervical injuries than mid-cervical injuries, more patients may have been in this DVT-prevalent state, leading to a significantly higher incidence of DVT in the present study.

Significantly fewer lower-cervical injuries caused upper extremity paralysis than mid-cervical injuries; however, 25% of patients with lower-cervical injuries developed C5-level muscle weakness, and 39% developed C6-level weakness. From a neurological standpoint, these symptoms are more extensive than expected; differences in ISI expansion on MR images may account for observed differences between expected and actual symptoms and upper extremity muscle preservation based on the level of injury. Patients with lower-cervical injuries experience neurological deficits and symptoms at levels remote from the level where the injury occurred. Thus, the ISI range may reflect symptom severity and neurological prognosis[24]. Histologically, a spinal cord injury is initiated through direct compression of the nerve tissue, leading to radial and axial propagation of microscopic within-cord hemorrhages over the course of several hours[25]. Patients with lower-cervical injuries resulting from high-energy trauma are likely to demonstrate more extensive injuries than those with mid-cervical injuries. Second, elderly patients can experience cervical spinal cord injuries as a result of even minor trauma that causes no concomitant fractures[24,26] because when a degenerated cervical spine hyperextends, the spinal cord compresses (degenerative cervical myelopathy)[27-29]. Hence, elderly patients with lower-cervical spine hyperextension injuries may also exhibit injuries at other levels. Consequently, patients with lower-cervical injuries may also suffer from tetraplegia as may patients with mid-cervical injuries; the two groups demonstrate similar mortality, pneumonia, and tracheostomy incidences. In other words, the fatal complication rate remains relatively unchanged, even considering the relative abundance of lower-cervical injuries.

This study had several limitations. First, it was a retrospective study; thus, selection bias may have existed. Second, the timing of MRI studies varied considerably. Some patients were imaged on the day of their injury, and others were not until several days later. Third, our study cohort was relatively small and dropouts occurred during the follow-up period. Finally, as this study was limited to elderly patients, we cannot exclude the influence of aging itself.

Conclusion

The present study found that proportionally, significantly more elderly patients with lower-cervical fracture/dislocation had high-energy trauma as the cause of their injuries than did patients with mid-cervical injuries. Although patients with lower-cervical injury had a significantly lower incidence of upper extremity muscle weakness, half of them suffered C5 muscle weakness.

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Author Contributions: N.S. designed the study; N.S. S.I., J.O., N.Y., T.S., T.F., A.Y., T.F., F.E., K.W., S.N., S.I., M.U., K.H., Y.O., H.N., H.S., Y.I., T.Y., T.H., K.K., Y.H., Y.T., R.H., H.T., M.S., Y.I., H.U., N.S., K.A., H.T., S.S., Y.O., T.K., B.O., K.N., K.K., H.F., T.Y., D.S., T.O., M.M., H.T., and G.I. collected the data; N.S. and H.N. wrote the manuscript; S.O., S.I., and S.K. supervised the project.

Ethical Approval: Thirty-three health care facilities were included in the database. The Institutional Review Board of each of the 25 representative institutions approved the study protocol (no. 3352-1).

Informed Consent: Owing to the retrospective design of the study, informed consent was not required. The optout of this study was posted on the website (https://web.sapmed.ac.jp/orsurg/guide/hj0g2h00000007ax-att/pgsps60000000g3l.pdf), and we did not receive any inquiries.

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