J Orthop Sci (2010) 15:485–492
DOI 10.1007/s00776-010-1493-x

JOURNAL OF
ORTHOPAEDIC SCIENCE

Original article

Upper cervical spine injuries: age-specific clinical features

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Abstract

Background. There are few reports on the age-specific clinical features of upper cervical spine injury. To identify these age-specific changes, we reviewed 103 patients with upper cervical spine injury.

Methods. We subdivided the patients into four groups according to age: 12 patients were classified as old elderly (≥75 years), 18 patients as young elderly (65–74 years), 67 patients as young adults (18–64 years), and 6 patients as adolescents (≤17 years). Data were collected on injury etiology, mortality, neurological deficit, distribution and pattern of injury, degenerative changes of each joint in the upper cervical spine and disc in the cervical spine, and osteoporosis of the axis.

Results. The proportion of patients with a simple fall as the etiology of their injury showed a statistically significant trend to increase with aging. Although no specific distribution or pattern of injury was statistically elucidated, we were able to detect some common features. A high proportion of the old elderly group (5/12) had a type II odontoid fracture. Body fracture of the axis tends to be frequent in the young elderly and traumatic spondylolisthesis and hyperextension teardrop fracture to be frequent in the young adults. In adolescents, a traffic accident as an unbelted rear seat passenger was the most frequent etiology. Among the 103 patients, 16 died during the initial hospitalization. The mortality rate for upper cervical spine injury was similar in all groups.

Conclusions. In the old elderly, stiffness of the lower cervical spine, caused by degenerative changes and osteopenia, might contribute to upper cervical spine injury in response to low-energy trauma. The disproportion of degenerative change in joints of the upper cervical spine might also contribute to the high frequency of type II odontoid fracture. In young adults, high-energy and hyperextension injury was the most frequent cause of upper cervical spine injury.

Offprint requests to: M. Watanabe
Received: October 7, 2009 / Accepted: April 19, 2010

Introduction

Data from different parts of the world show a trend toward decreasing neck injury incidence for age groups <65 years, whereas the incidence has remained constant or has increased in the elderly.[1–3] The cervical spine injury rates per 100 000 person-years for people aged <65 years and ≥65 years were reported to be 1.88 and 4.75 by Chen et al.[4] and 6.4 and 12.4 by Hu et al.[5] In young adults, most trauma causing cervical spine injury involves high-energy injury, such as falls from greater than standing height, motor vehicle accidents, and pedestrians knocked down by a car or a motorcycle. In contrast, in older people, cervical spine injury is more likely to be caused by a low-energy injury, such as a fall from standing or seated height.[6–13] Previous studies of cervical spine fractures in the elderly show a higher proportion of first and second cervical vertebral fractures compared with younger patients.[6,7,9,10,13,14] Upper cervical spine injuries account for 68.9% of all cervical spine injuries in the elderly and 35.8% in younger people.[14]

In a younger individual, C4-C7 is the most mobile segment of the cervical spine. With degenerative changes, these same segments become stiffer; and the C1/2 segment becomes the most mobile portion of the cervical spine in the elderly patients,[6,9,11] predisposing the atlantoaxial segment to injury with relatively trivial trauma. Odontoid fracture is the most frequent individual fracture of the cervical spine in people aged ≥65 years.[6,9,10–13,15,16] Even those in the most aged group, the old elderly (≥75 years), are reported to be more likely to sustain a fracture at the craniocervical junction than the young elderly (65–74 years).[9,10,12]

These differences suggest that age-related changes play a role in the pathology of cervical spine injury. Aging changes (e.g., osteoarthritis, osteopenia) also occur in the upper cervical spine, and the clinical features of upper cervical spine injury might differ according to age. To our knowledge, there are few reports on the age-specific clinical features of upper cervical spine injury. The aim of this study was to identify the age-specific clinical features of upper cervical spine injuries.

Patients and methods

Our series included 103 patients who sustained an acute upper cervical spine injury between April 1994 and March 2009 and were treated at our institution. We confirmed the fracture or dislocation in the upper cervical region (from the occipital condyle to the axis) in all patients using computed tomography (CT) images. The patients included 67 males and 36 females, whose mean age at injury was 49 years (range 4–89 years). The patients were subdivided into four groups according to age: 12 patients (8 men, 4 women) were classified as old elderly (≥75 years), 18 patients (9 men, 9 women) as young elderly (65–74 years), 67 patients (42 men, 25 women) as young adults (18–64 years), and 6 patients (4 boys, 2 girls) as adolescents (≤17 years).

The following information was recorded retrospectively. Injury etiology was recorded as a fall from a seated or standing height or a fall from greater than standing height; an injury sustained as a pedestrian, cyclist, motorcyclist, or motor vehicle occupant in a traffic accident; an injury sustained during a sporting activity; or other causes.

Mortality was assessed by distinguishing between deaths due to upper cervical spine injury and those due to complicated injuries or complications. Neurological injury on discharge from the initial hospitalization was assessed according to the classification of Frankel et al.[17] for surviving patients, although in some patients the neurological evaluation was impossible because of the brain injuries.

The distribution and pattern of injuries in the upper cervical spine were classified from CT images, using the method of Harris et al.,[18] into occipital condylar fracture and atlantooccipital dissociation at the C0 level, anterior arch fracture, posterior arch fracture, lateral mass fracture, Jefferson burst fracture, atlantoaxial dislocation at the C1 level, odontoid fracture, body fracture, traumatic spondylolisthesis, and hyperextension teardrop fracture at the C2 level. We modified the C1 rotatory subluxation and classified it as atlantoaxial dislocation. Odontoid fractures were further classified according to the method of Anderson and D'Alonso.[15]

We classified the degeneration of the atlantoodontoid, atlantooccipital, and lateral atlantoaxial joints and osteoporosis at the dens–body junction into none, mild, moderate, or severe based on CT image findings according to the method of Lakshmanan et al.[19] (Tables 1–3). Cervical degeneration below the axis was assessed using the cervical degenerative index (CDI) factor scoring proposed by Ofiram et al.[20] (Table 4). We investigated the CDI at five cervical levels (C2/3, C3/4, C4/5, C5/6, C6/7) and calculated an average CDI for each patient. Two reviewers reviewed each of the radiograms and CT images in a blinded manner and discussed them if there was a difference between the reviewers.

Table 1. Grading the severity of degenerative changes in the atlantoodontoid joint

Grade	Definition
None	Normal joint space with no osteophyte formation
Mild	Narrowed joint space or normal joint space with osteophyte formation
Moderate	Obliterated joint space with or without osteophyte formation
Severe	Ankylosis of joint with excrescences either in the joint or transverse ligament calcification, or both

Table 2. Grading the severity of degenerative changes in the atlantooccipital and lateral atlantoaxial joint

None	Normal joint space with no osteophyte formation
Mild	Narrowed joint space or normal joint space with osteophyte formation
Moderate	Obliterated joint space with or without osteophyte formation
Severe	Completely obliterated joint space with osteophyte excrescences and/or fusion of the joint

Table 3. Grading the severity of osteoporosis of the axis vertebra at the dens–body junction and in the odontoid process and the body of the axis

None	Normal trabecular pattern with normal cortical thickness
Mild	Decrease in the amount of trabeculae with no areas of absent trabeculae (holes) and normal cortical thickness
Moderate	Absent trabeculae (holes) involving <50% of the transverse diameter of the bone with cortical thinning
Severe	Absent trabeculae (holes) involving >50% of the transverse diameter of the bone with cortical thinning

Table 4. Cervical degenerative index factor scoring

Factor	0	1	2	3
Disc space narrowing	None	25%	50%	75%
Endplate or facet sclerosis	None	Minimal	Moderate	Severe
Osteophyte	None	<2 mm	2–4 mm	>4 mm
Olisthesis	None	<3 mm	3–5 mm	>5 mm

Table 5. Etiology of injury

Etiology	Total (n = 103)	Old elderly (n = 12)	Young elderly (n = 18)	Young adult (n = 67)	Adolescent (n = 6)
Fall from standing or seated height*	12	5	3	4	0
Fall from greater than standing height	34	4	9	20	1
Traffic accident (pedestrian)	9	0	3	6	0
Traffic accident (cyclist)	7	1	0	4	2
Traffic accident (motorcyclist)	5	0	0	5	0
Traffic accident (motor vehicle occupant)	30	1	3	23	3
Injury during sporting activity	3	0	0	3	0
Others	3	1	0	2	0

*Statistically significant in the proportion of the simple fall. Fisher's exact test for linear trend ($P < 0.01$)

Data were analyzed using PASW Statics 18 (SPSS Japan, an IBM company). The proportion of the trivial fall in the injury etiology; the proportion of Jefferson burst fracture, type II odontoid fracture, body fracture of the axis, traumatic spondylolisthesis, hyperextension teardrop fracture (there were more than 10 of these injuries); the proportion of mortality; the proportion of moderate and severe degenerative changes of the atlantoodontoid joint, atlantooccipital joint, and lateral atlantoaxial joint and in osteoporosis of the axis vertebra were compared by application of a two-tailed Fisher's exact test for linear trend in each age group. Tukey's HSD multiple comparison test was used to evaluate the differences in CDI between each age group. Significance was set at $P < 0.05$.

The study protocol and publication of this material were approved by the committee on ethics and the institutional review board of our institution.

Results

A total of 5 of 12 patients in the old elderly group and 3 of 18 patients in the young elderly group sustained an upper cervical injury from a simple fall. In the other patients, the injury was caused by high-energy trauma. Injuries caused by transport accidents in cyclists and motorcyclists and those caused by sporting activity were noted in the young adult group. In adolescents, three of six injuries were sustained in a traffic accident to an unbelted rear seat passenger. The proportion of a simple fall causing the injury increased in a statistically significant linear-by-linear association with aging ($P < 0.01$) (Table 5).

Table 6 shows the distribution and pattern of injuries in the upper cervical spine for each group. If the patient had combined injuries, each injury was counted. In all patients, traumatic spondylolisthesis (26 cases) and type II odontoid fracture (23 cases) were the most frequent, followed by a Jefferson burst fracture (14 cases). No patient had a type I odontoid fracture. The proportions of the Jefferson burst fracture ($P = 0.842$), type II odontoid fracture ($P = 0.084$), body fracture of the axis ($P = 0.823$), traumatic spondylolisthesis ($P = 0.745$), and hyperextension teardrop fracture ($P = 0.272$) did not show the statistically significant trend in any age group. However, type II odontoid fractures accounted for 5 of 12 injuries in the old elderly. Altogether, 4 of 11 cases of body fracture of the axis were in the young elderly, and 16 of 26 cases of traumatic spondylolisthesis and 11 of 12 cases of hyperextension teardrop fracture were in young adults. These findings showed the tendency of the age-specific features of the upper cervical injury.

In all, 16 of 103 patients (2 old elderly, 2 young elderly, 10 young adult, 2 adolescents) died during the initial hospitalization; some of these patients had been revived with cardiopulmonary resuscitation in the emergency unit or ambulance. The proportion of mortality did not show statistical significance in any age group ($P = 0.852$). Among these patients, the upper cervical spine injury might have been the direct cause of death in none of the old elderly, one young elderly (atlantooccipital dissociation combined with Jefferson burst fracture), four young adults (two with atlantooccipital dissociation and

Table 6. Distribution and pattern of injuries of the upper cervical spine

Injury	Total (*n* = 103)	Old elderly (*n* = 12)	Young elderly (*n* = 18)	Young adult (*n* = 67)	Adolescent (*n* = 6)
C0					
Occipital condylar fracture	2	0	0	1	1
Atlantooccipital dissociation	4	0	1	3	0
C1					
Anterior arch fracture	3	0	1	2	0
Posterior arch fracture	7	3	0	2	2
Lateral mass fracture	6	0	2	4	0
Jefferson burst fracture	14	1	3	10	0
Atlantoaxial dislocation	2	0	0	2	0
C2					
Odontoid fracture type I	0	0	0	0	0
Odontoid fracture type II	23	5	4	13	1
Odontoid fracture type III	3	0	0	2	1
Body fracture	11	0	4	6	1
Traumatic spondylolisthesis	26	3	6	16	1
Hyperextension teardrop fracture	12	1	0	11	0

Table 7. Mortality and neurological deficits

Parameter	Total (*n* = 103)	Old elderly (*n* = 12)	Young elderly (*n* = 18)	Young adult (*n* = 67)	Adolescent (*n* = 6)
Mortality					
Upper cervical lesion	6	0	1	4	1
Others	10	2	1	6	1
Neurological deficit (Frankel)					
A	2	0	1	1	0
B	2	0	0	2	0
C	7	1	2	3	1
D	13	2	1	10	0
E	57	6	10	38	3
Others	6	1	2	3	0

two with atlantoaxial dislocation), and one adolescent (body fracture of the axis). Although three patients with atlantooccipital dissociation died, one patient survived because his injury involved his head being sucked slowly into an air conditioner machine fitting and he suffered a lateral type of atlantooccipital dissociation, which is extremely rare. No patient died because of traumatic spondylolisthesis or type II odontoid fracture. In the old elderly, the causes of death included combined injuries involving subarachnoid hemorrhage after head injury and complications such as acute myocardial infarction. The causes of death from complicated injuries and complications in the other groups included one subarachnoid hemorrhage in a young elderly patient, one caused by brain injury, three that could not be distinguished between upper cervical spine injury and brain injury, one from abdominal injury, and one from disseminated intravascular coagulation in young adults; there was also one brain injury combined with an occipital condylar fracture in an adolescent. In all groups, most patients who survived showed relatively minor neurological deficits, such as grade D or E in Frankel's classification (Table 7).

The severity of the degenerative changes in the atlantoodontoid joint was graded using the CT axial and sagittal images. Nine of twelve old elderly patients and four of the five type II odontoid fractures were classified as having severe degenerative changes (Fig. 1). The severity of osteoporosis of the axis was evaluated from the CT axial images. Patients with moderate or severe osteoporosis accounted for 8 of 12 old elderly, 12 of 18 young elderly, 6 of 67 young adults, and none of 6 adolescents (Table 8)

The severity of the degenerative changes in the atlantooccipital and lateral atlantoaxial joints were graded from 5 of 12 old elderly, 13 of 18 young elderly, 34 of 67 young adults, and two of 6 adolescents using the CT sagittal and coronal images (Table 9) The proportion of moderate and severe showed statistically significant trend in the degenerative changes in the atlantoodontoid joint ($P < 0.01$), osteoporosis of the axis ($P < 0.01$), and degenerative changes in the atlantooccipital joint

Fig. 1. Severe degenerative change of the atlantoodontoid joint. Sagittal computed tomography (CT) of an 83-year-old man with a type II odontoid fracture shows ankylosis of the atlantoodontoid joint with transverse ligament calcification (*arrow*)

($P = 0.021$). Degenerative changes associated with aging were less prominent in the lateral atlantoaxial joints ($P = 0.233$). The CDI (mean ± SEM) was 4.05 ± 0.67 in the old elderly, 2.34 ± 0.63 in the young elderly, 0.94 ± 0.57 in young adults, and 0 in adolescents. The CDI differed significantly between all groups ($P < 0.01$) except for the comparison between the young adults and adolescents ($P = 0.357$) (Fig. 2).

Discussion

Previous studies of cervical spine fractures in the elderly have noted that most are caused by a simple fall and that first or second cervical vertebra fractures occur more frequently in the elderly than in younger people.[6,7,9,10,13,14] In this study, as a fall from standing or

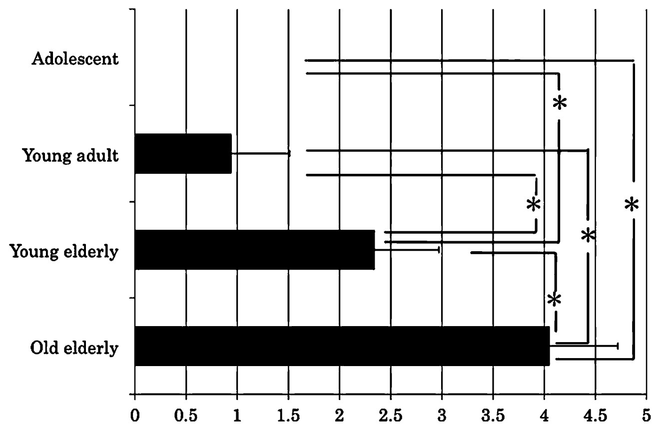

Fig. 2. Average cervical degenerative index for each group. *Error bars* indicate the mean ± SEM. *Asterisks* denote a significant difference at $P < 0.01$ between the bracketed values

Table 8. Grading the severity of degenerative changes in the atlantoodontoid joint and osteoporosis of the axis vertebra at the dens–body junction

Grade	Old elderly ($n = 12$)	Young elderly ($n = 18$)	Young adult ($n = 67$)	Adolescent ($n = 6$)
Atlantoodontoid joint*				
None	2	1	38	6
Mild	1	6	17	0
Moderate	0	6	6	0
Severe	9	4	5	0
Unknown	0	1	1	0
Osteoporosis of axis vertebra*				
None	1	1	42	6
Mild	3	4	17	0
Moderate	5	10	5	0
Severe	3	2	1	0
Unknown	0	1	2	0

* Statistically significant in the proportion of moderate and severe grades. Fisher's exact test for linear trend ($P < 0.01$)

Table 9. Grading the severity of degenerative change in the atlantooccipital and lateral atlantoaxial joints

Grade	Old elderly ($n = 5$)	Young elderly ($n = 13$)	Young adult ($n = 34$)	Adolescent ($n = 2$)
Atlantooccipital joint*				
None	1	0	22	2
Mild	2	6	7	0
Moderate	2	4	5	0
Severe	0	3	0	0
Lateral atlantoaxial joint				
None	4	6	29	2
Mild	0	7	4	0
Moderate	1	0	1	0
Severe	0	0	0	0

*Statistically significant in the proportion of the moderate and severe grades. Fisher's exact test for linear trend ($P < 0.05$)

a seated height accounted for 42% of the fractures in the old elderly and 17% in the young elderly, this proportion demonstrated a statistically significant linear trend in each age group. The elderly have a higher risk of falling than younger people because of reduced visual activity, reduced reaction time, and blunted reflexes.[7] The elderly also have a higher risk of fractures after minor trauma because of the biochemical bone attrition associated with senile osteopenia, the most common cause of primary osteoporosis.[9–11] In a younger individual, the lower cervical spine region (C4-C7) is the most mobile segment of the cervical spine. Because degenerative osteoarthritis primarily affects the facet joint below the axis,[21,22] in older people the lower segments become stiffer and the C1/2 segment becomes the most mobile portion of the cervical spine.[6,9,11,23]

It is difficult to evaluate range of motion (ROM) after a cervical spine injury. In this study, we used the CDI proposed by Ofiram et al.[20] to analyze quantitatively the degenerative changes in the lower cervical spine. The CDI in the old elderly was significantly higher than in the young elderly.

The proportion of patients with moderate or severe osteoporosis at the dens–body junction also increased significantly in each age group. These results suggest that the stiffness of the lower cervical spine caused by degenerative changes and osteopenia by osteoporosis contributes to injury of the upper cervical spine after low-energy trauma in the old elderly. In the younger groups, except for four patients, the upper cervical spine injuries were caused only by high-energy trauma. An interesting finding in the etiology of injury in the younger patients was that half of the adolescents were injured in a traffic accident as an unbelted rear seat passenger, thereby reinforcing the view that all motor vehicle occupants should wear seatbelts.

Although we could not demonstrate an age-specific distribution and pattern of injuries to the upper cervical spine, several common features were noted. Type II odontoid fracture is reported to be the most frequent individual fracture of the cervical spine in people aged ≥65 years.[6,9–13,15,16] We also found that type II odontoid fractures accounted for 5 of 12 injuries in the old elderly. The disproportion of degenerative changes in joints of the upper cervical spine might be associated with the high frequency of type II odontoid fractures in the old elderly. The incidence of degenerative changes in the atlantoodontoid joint in healthy older people is high — 42% during the seventh decade and 60.9% during the eighth decade — and these changes contribute to the obliteration of the atlantoodontoid joint space.[24] The incidence of degenerative changes in the lateral atlantoaxial joint is 4.0%–18.2% in normal adults.[25,26] In our series, degenerative change in the atlantoodontoid and atlantooccipital joints showed a statistically significant linear trend in each age group. On the other hand, degenerative change of the lateral atlantoaxial joint did not show a statistically significant correlation with aging.

Lakshmanan et al.[19] reported a significant relation between upper cervical spine osteoarthritis and the incidence of type II odontoid fracture. Severe degenerative changes in the atlantoodontoid joint develop progressively with aging. They eventually obliterate the joint space and fix the odontoid to the anterior arch of the atlas. In contrast, the lateral atlantoaxial joints are hardly affected by osteoarthritis. Low-energy trauma induces forced atlantoaxial rotation, which along with marked limitation of movement at the atlantoodontoid joint can produce a torque force at the base of the odontoid process.

In the young elderly, the number of body fractures of the axis equaled the number of type II odontoid fractures. All young elderly patients with vertebral body fractures showed moderate or severe osteoporosis of the axis body and were injured with high-energy trauma. This suggests that a combination of high-energy injury and osteopenia increases the risk of vertebral body fracture in this age group.

Most of the hyperextension teardrop fractures (11/12) were found in the young adults, and traumatic spondylolisthesis and hyperextension teardrop fracture accounted for 27 of 67 of the upper cervical injuries in this age group. Levine and Edwards[27] reported that most traumatic spondylolisthesis (44/52) resulted from a hyperextension-axial loading force (types I and II). High-energy and hyperextension injuries were the most frequent causes of upper cervical spine injury in the young adults.

Death resulting from respiratory failure is of great concern in patients with an upper cervical spine injury. We were able to find only a few reports on the age-specific mortality rate associated with upper cervical spine injuries. In our institution, we investigated CT images of the head and cervical spine during resuscitation of trauma patients declared dead on arrival (DOA), which accounted for the small number of DOA patients who had upper cervical spine injuries that had been overlooked. In this study, the total mortality was 15.5%. Among the patients who died, upper cervical spine injury might have been a direct cause of death in six. The patterns of injury causing death were atlantooccipital dissociation (three patients), atlantoaxial dislocation (two patients), and body fracture of the axis (one patient). All of these injuries were caused by high-energy trauma, and most were in the young adult group. Because of the small number of high-energy injuries in the old elderly, there were no deaths caused by upper cervical spine injury in this group.

The mortality rates at initial hospitalization were similar in all groups. On the other hand, a high mortality rate due to cervical spine injury in the elderly has been reported.[7,13,28] Spivak et al.[13] reported an overall mortality rate for the initial hospitalization period of patients with cervical spine injury as follows: 25.9% in patients >65 years versus 0.5% in patients <40 years. In a national survey of Sweden by Brolin,[6] people aged >65 years made up 17% of the population and sustained 30% of all cervical injuries and 43% of all fatal cervical injuries. The high mortality rate associated with cervical spine injury is related to the serious neurological deficits and respiratory complications associated with prolonged bed rest.[7,9,13,29,30] However, these were reported for all cervical spine injuries, not just upper cervical injuries. In our study, because serious neurological deficits occurred less often with upper cervical injury and most patients in the old elderly group were injured by low-energy trauma, the mortality rate associated with upper cervical spine injury was similar in the elderly patients and the other age groups.

Conclusions

We clarified the age-specific clinical features of upper cervical spine injuries. The old elderly patients were more likely to experience type II odontoid fracture with low-energy trauma. The stiffness of the lower cervical spine, caused by degenerative changes and osteopenia by osteoporosis, might contribute to upper cervical spine injury in response to low-energy trauma. The disproportion of degenerative change in joints of the upper cervical spine might also contribute to the high frequency of type II odontoid fracture. In the young elderly, injury of the upper cervical spine was less frequently caused by low-energy trauma than in the old elderly, and body fracture of the axis was noted. In young adults, traumatic spondylolisthesis and hyperextension teardrop fractures were seen. High-energy and hyperextension injuries were the most frequent cause of upper cervical spine injury in young adults. Among the adolescents, half were injured as an unbelted rear seat passenger in a traffic accident. Hence, all motor vehicle occupants should wear seatbelts, even when in the pillion seat.

Acknowledgments. The authors are grateful to Prof. Hiroyuki Kobayashi and Mitsuhiro Isozaki, MS (Department of Clinical Pharmacology, Tokai University School of Medicine) for their advice on the statistical analysis.

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this article.

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