A multicenter study of 1-year mortality and walking capacity after spinal fusion surgery for cervical fracture in elderly patients

Takeshi Sasagawa
Kanazawa University
Noriaki Yokogawa
Kanazawa University
Hiroyuki Hayashi
Kanazawa University
Hiroyuki Tsuchiya
Kanazawa University
Kei Ando
Nagoya University
Hiroaki Nakashima
Nagoya University
Naoki Segi
Nagoya University
Kota Watanabe
Keio University School of Medicine
Satoshi Nori
Keio University School of Medicine
Kazuki Takeda
Keio University School of Medicine
Takeo Furuya
Chiba University
Atsushi Yunde
Chiba University
Shota Ikegami
Shinshu University School of Medicine
Masashi Uehara
Shinshu University School of Medicine
Hidenori Suzuki
Yamaguchi University Graduate School of Medicine
Yasuaki Imajo

Yamaguchi University Graduate School of Medicine
Toru Funayama
University of Tsukuba
Fumihiko Eto
University of Tsukuba
Akihiro Yamaji
Ibaraki Seinan Medical Center Hospital
Ko Hashimoto
Tohoku University Graduate School of Medicine
Yoshito Onoda
Tohoku University Graduate School of Medicine
Kenichiro Kakutani
Kobe University Graduate School of Medicine
Yuji Kakiuchi
Kobe University Graduate School of Medicine
Nobuyuki Suzuki
Nagoya City University Graduate School of Medical Sciences
Kenji Kato
Nagoya City University Graduate School of Medical Sciences
Yoshinori Terashima
Sapporo Medical University
Ryosuke Hirota
Sapporo Medical University
Tomohiro Yamada
Hamamatsu University School of Medicine
Tomohiko Hasegawa
Hamamatsu University School of Medicine
Kenichi Kawaguchi
Kyushu University
Yohei Haruta
Kyushu University
Shoji Seki
University of Toyama
Hitoshi Tonomura
Kyoto Prefectural University of Medicine
Munehiro Sakata
Kyoto Prefectural University of Medicine
Hiroshi Uei
Nihon University Hospital

Hirokatsu Sawada
Nihon University School of Medicine
Hiroyuki Tominaga
Kagoshima University
Hiroto Tokumoto
Kagoshima University
Takashi Kaito
Osaka University Graduate School of Medicine
Yoichi Iizuka
Gunma University
Eiji Takasawa
Gunma University
Yasushi Oshima
The University of Tokyo Hospital
Hidetomi Terai
Osaka City University Graduate School of Medicine
Koji Tamai
Osaka City University Graduate School of Medicine
Bungo Otsuki
Kyoto University
Masashi Miyazaki
Oita University
Hideaki Nakajima
University of Fukui
Kazuo Nakanishi
Kawasaki Medical School
Kosuke Misaki
Kawasaki Medical School
Gen Inoue
Kitasato University School of Medicine
Katsuhito Kiyasu
Kochi University
Koji Akeda
Mie University Graduate School of Medicine
Norihiko Takegami
Mie University Graduate School of Medicine
Toshitaka Yoshii
Tokyo Medical and Dental University
Masayuki Ishihara

Kansai Medical University Hospital

Seiji Okada

Osaka University Graduate School of Medicine

Yasuchika Aoki

Eastern Chiba Medical Center

Katsumi Harimaya

Kyushu University Beppu Hospital

Hideki Murakami

Nagoya City University Graduate School of Medical Sciences

Ken Ishii

International University of Health and Welfare

Seiji Ohtori

Chiba University

Shiro Imagama

Nagoya University

Satoshi Kato (skato323@gmail.com)

Kanazawa University

Research Article

Keywords: Cervical fracture, Spinal fusion surgery, Elderly, Mortality, Walking capacity

Posted Date: March 28th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1411249/v1

Abstract

Background: The 1-year mortality and functional prognoses of patients who received surgery for cervical trauma in the elderly remains unclear. The aim of this study is to investigate the rates of, and factors associated with mortality and the deterioration in walking capacity occurring 1 year after spinal fusion surgery for cervical fractures in patients 65 years of age or older.

Methods: 313 patients aged 65 years or more with a traumatic cervical fracture who received spinal fusion surgery were enrolled. The patients were divided into a survival group and a mortality group, or a maintained walking capacity group and a deteriorated walking capacity group. We compared patients' backgrounds, trauma, and surgical parameters between the two groups. To identify factors associated with mortality or a deteriorated walking capacity 1 year postoperatively, a multivariate logistic regression analysis was conducted.

Results: One year postoperatively, the rate of mortality was 8%. A higher Charlson comorbidity index (CCI) score, a more severe the American Spinal Cord Injury Association impairment scale (AIS), and longer surgical time were identified as independent factors associated with an increase in 1-year mortality. The rate of deterioration in walking capacity between pre-trauma and 1 year postoperatively was 33%. A more severe AIS, lower total protein (TP), and lower hemoglobin (Hb) values were identified as independent factors associated with the increased risk of deteriorated walking capacity 1 year postoperatively.

Conclusions: The 1-year rate of mortality after spinal fusion surgery for cervical fracture in patients 65 years of age or older was 8%, and its associated factors were a higher CCI score, a more severe AIS, and a longer surgical time. The rate of deterioration in walking capacity was 33%, and its associated factors were a more severe AIS, lower TP and Hb values.

Background

In step with the overall aging of the population, the frequency of occurrence of cervical spinal fractures in the elderly has increased in recent years [1, 2]. Cervical spine fractures may occur in isolation or in conjunction with a spinal cord injury and are relatively common among older adults, whose susceptibility may increase with minor trauma. Cervical spine fractures represent an important cause of mortality among adults aged 65 years or older [1, 2]. The mortality associated with cervical spinal fractures in elderly patients exceeds that in younger patients [3]. Compared with a hip fracture, a common type of fracture in the elderly, patients with cervical fractures had a greater mortality than those with hip fractures [1]. Surgical treatment for cervical trauma is a more invasive option compared with conservative treatment. Therefore, it is important to understand mortality and functional outcomes after surgical treatment for cervical trauma.

In previous reports that have explored the relationship between mortality and cervical spinal fractures in the elderly, only in-hospital mortality has been discussed [2–5], and only a few reports have referred to 1 year mortality [6, 7]. Furthermore, most of the previous reports included both surgical and conservative treatments [2–6], and few reports specify the mortality of patients treated with surgery alone [7]. The 1-year mortality of patients who received surgery for cervical trauma remains unclear. Moreover, to our knowledge, although functional outcomes after surgery for cervical trauma are important, 1-year postoperative functional prognoses remain unreported. The aim of this study is to investigate the rates of, and factors associated with mortality and any changes in walking capacity occurring 1 year after spinal fusion surgery for cervical fractures in patients 65 years of age or older.

Materials And Methods

Study design and ethical considerations

This study retrospectively analyzed multicenter registry data collected by the Japan Association of Spine Surgeons with Ambition (JASA). The institutional review board of the representative facility reviewed and approved this study. No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Patient population

Patients aged 65 years or more with a traumatic cervical fracture who received spinal fusion surgery from February 2010 to August 2019 at 68 institutions registered with JASA were considered for inclusion in this study. Patients who received surgery more than 90 days postinjury, or those for whom missing data pertaining to the type of surgery and level(s) of fusion were missing, were excluded. Of the 418 patients who were eligible for study participation, 105 of them were lost to follow-up 1 year postoperatively (follow-up rate was 75%) and 313 patients were enrolled.

Data collection

Patients' background data

Data for each patient, including age at time of injury, gender, height, weight, pre-trauma walking capacity, Charlson Comorbidity Index (CCI) score [8], and blood test results at the first visit were collected. Patients' walking capacities were divided into four grades: independent, able to walk with a T-cane, able to walk with a walker, or inability to walk. Blood tests were used to measure total protein (TP) and hemoglobin (Hb).

Trauma data

Collected radiographic data included the fracture level(s), presence of facet interlocking, and comorbid major organ injury. Comorbid major organ injury was defined as other trauma requiring surgery, hemothorax requiring a chest drain, or brain injury with consciousness disturbance. Neurological impairment was accessed using the American Spinal Cord Injury Association (ASIA) impairment scale (AIS), ranging from Grade A (complete impairment) to Grade E (normal function). [9]

Surgical data

The surgical data documented included the surgical approach (anterior, posterior, or combined), number of fused levels, presence of occipitocervical fusion, surgical bleeding (mL), and surgical time (min).

Operative outcomes

Collected operative outcomes included intraoperative and postoperative complications, patient mortality, and walking capacity 1 year postoperatively.

Statistical analysis

All 313 patients were divided into a survival group and a mortality group. We also divided the patients who were able to walk before injury and survived 1 year postoperatively into a ‘maintained walking capacity’ group and a ‘deteriorated walking capacity’ group. Deteriorated walking capacity applied when a patient’s walking capacity decreased by at least one grade between pre-trauma and 1 year postoperatively. We compared patients’ backgrounds, trauma, and surgical parameters between the two groups. All data are expressed as mean ± standard deviation. A Mann–Whitney U test, chi square test, or Fisher’s exact test was used to compare each item. To identify factors associated with mortality or a deteriorated walking capacity 1 year postoperatively, a multivariate logistic regression analysis was conducted in which mortality or a deteriorated walking capacity were used as a dependent variable. Items that were significantly different by univariate analysis were independent variables. In a subgroup of patients with an AIS of C/D or E, a multivariate logistic regression analysis was also conducted to identify factors associated with a deteriorated walking capacity 1 year postoperatively. Differences were considered significant at $P < 0.05$. All statistical analyses were performed using IBM SPSS Statistics for Windows (version 22; IBM Corp, Armonk, NY).

Results

The demographic data for 313 cases are presented in Table 1. There were 201 men and 112 women of mean age 74.6 years in this study. Of the 313 patients we assessed, 99% were able to walk before injury. The most common site for cervical fractures was C6–7 (46%), followed by C3–5 (43%), and C1–2 (31%). The frequency of facet interlocking was 28%, and a spinal cord injury occurred in 51% of patients. Surgery was most frequently via the posterior approach (87%). The intraoperative and postoperative complications of the 313 cases are presented in Table 2. The most frequent intraoperative complication was an iatrogenic dural tear (2%), and the most frequent postoperative complication was pneumonia (11%).

Table 1
Patient characteristics and demographics

Parameter[a]	n	N (%)[b]
Patients, n		313
Age, years		74.6 ± 6.2
Gender (male: female), n		201:112
Height, cm	298	158.9 ± 9.7
Weight, kg	300	55.8 ± 10.3
Pre-trauma walking capacity, n		
Independent / T-cane / walker / inability to walk		291 / 13 / 5 / 4
Charlson comorbidity index	307	0.6 ± 1.0
Blood test data, g/dL		
Total protein	284	6.7 ± 0.7
Hemoglobin	309	12.6 ± 1.9
Level of fracture, n (%)		
C1–2 / C3–5 / C6–7		98 (31) / 113 (36) / 144 (46)
Facet interlocking, n (%)		89 (28)
ASIA Impairment Scale, n (%) A / B / C / D / E	312	27 (9) / 14 (5) / 43 (14) / 74 (24) / 154 (49)
Comorbid major organ injury, n (%)		31 (10)
Surgery		
Anterior / Posterior / Combined, n (%)		30 (10) /273 (87) / 10 (3)
Number of fused segments		2.4 ± 1.8
Occipitocervical fusion, n (%)		16 (5)
Surgical bleeding, mL	291	174 ± 71
Surgical time, min	288	247 ± 387

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for a denominator of N = 313, unless otherwise indicated by n in middle column.

ASIA American Spinal Injury Association

Table 2
Overall operative outcomes

Outcomes	N = 313
Intraoperative complications, n (%)	
Dural tear	7 (2)
Vertebral artery injury	4 (1)
Spinal cord injury	1 (< 1)
Postoperative complications, n (%)	
Pneumonia	33 (11)
Delirium	30 (10)
Urinary tract infection	27 (9)
Surgical site infection	6 (2)
Cerebral infarction	5 (2)
Instrumentation failure	4 (1)
Cerebrospinal fluid leakage	4 (1)
Pulmonary embolism	3 (1)
Epidural hematoma	1 (< 1)
1-year mortality, % Overall ASIA Impairment Scale A / B / C / D / E	8 44 / 14 / 5 / 1 / 5
Walking capacity deterioration 1-year postoperatively[a], % Overall ASIA Impairment Scale A / B / C / D / E	33 100 / 100 / 63 / 21 / 18
ASIA American Spinal Injury Association	
[a] n = 284 patients who can walk before injury	

Life prognosis

One year postoperatively, 25 out of 313 patients had died and the rate of mortality was 8% (Table 2). A comparison between the survival group (n=288) and the mortality group (n=25) revealed that being male, being assessed as having a higher CCI score, a severe AIS, and/or a longer surgical time were more significantly associated with the mortality group than the survival group (Table 3). A multivariate logistic regression analysis was conducted to identify factors associated with 1-year mortality. A higher CCI score (odds ratio [OR] = 2.046, 95% confidence interval [CI]: 1.398–2.993), more severe AIS (OR = 2.205, 95% CI: 1.586–3.065), and longer surgical time (OR = 1.009, 95% CI: 1.002–1.015) were identified as independent factors associated with an increase in 1-year mortality (Table 4).

Table 3
Comparison of admission data between survival and mortality groups 1 year postoperatively

	n	**Survival group (n = 288)**	n	**Mortality group (n = 25)**	***P***
Patient background					
Age, years		74.5 ± 6.3		76.6 ± 5.4	0.07
Gender (male / female), n		179 / 109		22 / 3	0.01*
Height, cm	274	158.7 ± 9.7	24	161.5 ± 9.9	0.19
Weight, kg	277	55.7 ± 10.3	24	56.8 ± 10.8	0.78
Pre-trauma walking capacity, n					
Independent / T-cane / walker / inability to walk		269 / 12 / 3 / 4		22 / 1 / 2 / 0	0.14
Charlson comorbidity index	282	0.5 ± 1.0		1.3 ± 1.6	< 0.01*
Blood test data, g /dL					
Total protein	265	6.7 ± 0.7	19	6.4 ± 0.7	0.21
Hemoglobin	285	12.7 ± 1.9	24	12.1 ± 2.3	0.33
Level of fracture, n (%)					
C1–2		93 (32)		5 (20)	0.20
C3–5		102 (35)		11 (44)	0.39
C6–7		130 (45)		14 (56)	0.30
Facet interlocking, n (%)		81 (28)		8 (32)	0.68
ASIA Impairment Scale, n (%)					< 0.01*
A / B / C / D / E	287	15 (5) /12 (4) / 41 (14) / 73 (25) / 146 (51)		12 (48) / 2 (8) / 2 (8) / 1 (4) / 8 (32)	

[a]Data are the mean ± standard deviation unless otherwise shown.
[b]Results for denominator n = 288 (survivor group) or n = 25 (mortality group), unless otherwise indicated in the column to the left of each of these group results, respectively.
ASIA American Spinal Injury Association
**P* < 0.05

	n	Survival group (n = 288)	n	Mortality group (n = 25)	*P*
Comorbid major organ injury, n (%)		30 (10)		1 (4)	0.26
Surgery					
Anterior / Posterior / Combined, n (%)		28 (10) / 251 (87) / 9 (3)		2 (8) / 22 (88) / 1 (4)	0.94
Number of fused segments		2.3 ± 1.7		3.0 ± 2.0	0.10
Occipitocervical fusion, n (%)		15 (5)		1 (4)	0.63
Surgical bleeding, mL	266	228 ± 304	22	481 ± 886	0.10
Surgical time, min	268	171 ± 68	23	217 ± 83	< 0.01*

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator n = 288 (survivor group) or n = 25 (mortality group), unless otherwise indicated in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

**P* < 0.05

Table 4
Multivariate logistic regression analysis of associated factors of mortality 1 year postoperatively

Variables	OR	95% CI	*P*
Gender	0.419	0.109–1.611	0.21
Charlson comorbidity index	2.046	1.398–2.993	< 0.01*
ASIA Impairment Scale	2.205	1.586–3.065	< 0.01*
Surgical time	1.009	1.002–1.015	0.01*

OR odds ratio; *CI* confidence interval; *ASIA* American Spinal Injury Association

**P* < 0.05

Walking capacity

Of 313 patients, 284 patients were able to walk before injury and survived 1 year postoperatively. Among these 284 patients, 93 patients (33%) exhibited a deterioration in their pre-trauma walking capacity 1 year postoperatively (Table 2). A comparison between the maintained walking capacity group (n=191) and the deteriorated walking capacity group (n=93) revealed the values of TP and Hb, and the frequency of C1—2 fractures were significantly less in the deteriorated walking capacity group. In contrast, the frequency of C3—5 fractures, severe AIS, number of fused segments, and surgical bleeding were significantly higher in the deteriorated walking capacity group than the maintained walking capacity group (Table 5). A multivariate logistic regression analysis was conducted to identify factors associated with deteriorated walking capacity 1 year postoperatively. A more severe AIS (OR = 3.862, 95% CI: 2.581–5.779), lower TP (OR = 0.400, 95% CI: 0.227–0.705), and lower Hb (OR = 0.745, 95% CI: 0.610–0.909) values were identified as independent factors associated with the increased risk of deteriorated walking capacity 1 year postoperatively (Table 6).

Table 5
Comparison of admission data between maintained and deteriorated walking capacity groups 1 year postoperatively

	n	**Maintained walking capacity group (n = 191)**	n	**Deteriorated walking capacity group (n = 93)**	***P***
Patient background					
Age, years		74.3 ± 6.2		74.6 ± 6.4	0.78
Gender (male / female), n		111 / 80		64 / 29	0.08
Height, cm	185	158.4 ± 9.7	85	159.3 ± 9.6	0.36
Weight, kg	186	55.0 ± 10.0	87	57.5 ± 10.9	0.07
Pre-trauma walking capacity, n					
Independent / T-cane / walker		183 / 6 / 2		86 / 6 / 1	0.35
Charlson comorbidity index	189	0.5 ± 1.0	89	0.6 ± 0.9	0.20
Blood test data, g /dL					
Total protein	175	6.8 ± 0.7	86	6.4 ± 0.6	< 0.01*
Hemoglobin	188	12.9 ± 1.9	84	12.3 ± 1.8	0.02*
Level of fracture, n (%)					
C1–2		71 (37)		22 (24)	0.02*
C3–5		59 (31)		41 (44)	0.03*
C6–7		86 (45)		42 (45)	0.98
Facet interlocking, n (%)		53 (28)		28 (30)	0.68

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator of n = 191 (maintained walking capacity group) or n = 93 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

$*P < 0.05$

	n	Maintained walking capacity group (n = 191)	n	Deteriorated walking capacity group (n = 93)	*P*
ASIA Impairment Scale, n (%)					< 0.01*
A / B / C / D / E		0 / 0 / 15 (8) / 57 (30)/ 119 (62)		15 (16) / 11 (12) / 25 (27) / 15 (16) / 27 (29)	
Comorbid major organ injury, n (%)		16 (8)		14 (15)	0.09
Surgery					
Anterior / Posterior / Combined, n (%)		20 (10) / 164 (86) / 7 (4)		7 (8) / 84 (90) / 2 (2)	0.56
Number of fused segments		2.1 ± 1.6		2.6 ± 1.9	0.01*
Occipitocervical fusion, n (%)		8 (4)		7 (8)	0.18
Surgical bleeding, mL	176	187 ± 220	86	291 ± 363	0.01*
Surgical time, min	181	168 ± 72	83	176 ± 60	0.25
Walking capacity 1 year postoperatively, n					
Independent / T-cane / walker / inability to walk		184 / 6 / 1 / 0		0 / 32 / 33 / 28	

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator of n = 191 (maintained walking capacity group) or n = 93 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

**P* < 0.05

Table 6
Multivariate logistic regression analysis of associated factors of deteriorated walking capacity 1 year postoperatively

Variables	**OR**	**95% CI**	***P***
Total protein	0.400	0.227–0.705	< 0.01*
Hemoglobin	0.745	0.610–0.909	< 0.01*
C1–2	0.512	0.217–1.213	0.13
C3–5	0.645	0.303–1.375	0.26
ASIA Impairment Scale	3.862	2.581–5.779	< 0.01*
Fused segments	1.123	0.909–1.387	0.28
Surgical bleeding	1.001	1.000–1.003	0.08

OR odds ratio; *CI* confidence interval; *ASIA* American Spinal Injury Association

*$P < 0.05$

Among 112 patients with an AIS of C/D, a comparison between the maintained walking capacity group (n=72) and the deteriorated walking capacity group (n=40) revealed the values of TP were significantly less in the deteriorated walking capacity group. In contrast, the number of fused segments were significantly larger in the deteriorated walking capacity group than the maintained walking capacity group (Table 7). A multivariate logistic regression analysis revealed a lower TP (OR = 0.345, 95% CI: 0.157–0.758) and a larger number of fused segments (OR = 1.274, 95% CI: 1.022–1.589) were identified as independent factors associated with the increased risk of deteriorated walking capacity 1 year postoperatively (Table 8). Among 146 patients with an AIS of E, a comparison between the maintained walking capacity group (n=119) and the deteriorated walking capacity group (n=27) revealed the values of TP and Hb were significantly lower in the deteriorated walking capacity group. In contrast, age and the frequency of poor pre-trauma walking capacity were significantly higher in the deteriorated walking capacity group than the maintained walking capacity group (Table 9). A multivariate logistic regression analysis revealed that a lower Hb (OR = 0.735, 95% CI: 0.563–0.961) values was identified as an independent factor associated with the increased risk of a deteriorated walking capacity 1 year postoperatively (Table 10).

Table 7
Comparison of admission data between maintained and deteriorated walking capacity groups 1 year postoperatively (AIS C/D)

	n	**Maintained walking capacity group (n = 72)**	n	**Deteriorated walking capacity group (n = 40)**	***P***
Patient background					
Age, years		74.1 ± 6.0		74.9 ± 6.9	0.58
Gender (male / female), n		45 / 27		27 / 13	0.68
Height, cm	70	159.8 ± 10.0	36	159.4 ± 9.6	0.86
Weight, kg	70	55.2 ± 10.7	36	58.8 ± 10.9	0.09
Pre-trauma walking capacity, n					
Independent / T-cane / walker		68 / 4 / 0		38 / 2 / 0	> 0.99
Charlson comorbidity index	70	0.5 ± 0.9	39	0.6 ± 0.8	0.36
Blood test data, g /dL					
Total protein	64	6.8 ± 0.6	35	6.5 ± 0.5	< 0.01*
Hemoglobin	71	13.1 ± 1.9		12.6 ± 1.7	0.12
Level of fracture, n (%)					
C1–2		9 (13)		9 (23)	0.19
C3–5		30 (42)		19 (48)	0.69
C6–7		41 (57)		19 (48)	0.43
Facet interlocking, n (%)		24 (33)		11 (28)	0.67
Comorbid major organ injury, n (%)		3 (4)		6 (15)	0.07

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator of n = 72 (maintained walking capacity group) or n = 40 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

*$P < 0.05$

	n	Maintained walking capacity group (n = 72)	n	Deteriorated walking capacity group (n = 40)	*P*
Surgery					
Anterior / Posterior / Combined, n (%)		12 (17) / 57 (79) / 3 (4)		2 (5) / 38 (95) / 0 (0)	0.10
Number of fused segments		2.1 ± 1.7		3.0 ± 2.1	0.02*
Occipitocervical fusion, n (%)		1 (1)		3 (8)	0.13
Surgical bleeding, mL	64	191 ± 195	37	281 ± 428	0.48
Surgical time, min	67	164 ± 78	35	186 ± 71	0.10
Walking capacity 1 year postoperatively, n					
(Independent / T-cane / walker / inability to walk)		68 / 4 / 0 / 0		0 / 15 / 17 / 8	

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator of n = 72 (maintained walking capacity group) or n = 40 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

*$P < 0.05$

Table 8
Multivariate logistic regression analysis of associated factors of deteriorated walking capacity 1 year postoperatively (AIS C/D)

Variables	OR	95% CI	*P*
Total protein	0.345	0.157–0.758	< 0.01*
Fused segments	1.274	1.022–1.589	0.03*

OR odds ratio; *CI* confidence interval

*$P < 0.05$

Table 9
Comparison of admission data between maintained and deteriorated walking capacity groups 1 year postoperatively (AIS E)

	n	Maintained walking capacity group (n = 119)	n	Deteriorated walking capacity group (n = 27)	*P*
Patient background					
Age, years		74.5 ± 6.4		77.6 ± 5.4	0.01*
Gender (male / female), n		66 / 53		16 / 11	0.83
Height, cm	115	157.5 ± 9.5	24	154.5 ± 9.0	0.22
Weight, kg	116	54.9 ± 9.5	25	53.8 ± 10.1	0.59
Pre-trauma walking capacity, n					
Independent / T-cane / walker		115 / 2 / 2		22 / 4 / 1	0.01*
Charlson comorbidity index		0.5 ± 1.0	24	0.6 ± 1.1	0.52
Blood test data, g /dL					
Total protein	111	6.8 ± 0.7		6.3 ± 0.7	< 0.01*
Hemoglobin	117	12.7 ± 1.9		11.2 ± 1.8	< 0.01*
Level of fracture, n (%)					
C1–2		62 (52)		11 (41)	0.39
C3–5		29 (24)		10 (37)	0.23
C6–7		45 (38)		7 (26)	0.27
Facet interlocking, n (%)		29 (24)		3 (11)	0.20
Comorbid major organ injury, n (%)		13 (11)		6 (22)	0.12

[a]Data are the mean ± standard deviation unless otherwise shown.

[b]Results for denominator of n = 119 (maintained walking capacity group) or n = 27 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.

ASIA American Spinal Injury Association

**P* < 0.05

	n	Maintained walking capacity group (n = 119)	n	Deteriorated walking capacity group (n = 27)	*P*
Surgery					
Anterior / Posterior / Combined, n (%)		9 (8) / 106 (89) / 4 (3)		3 (11) / 23 (85) / 1 (4)	0.56
Number of fused segments		2.1 ± 1.6		2.3 ± 1.8	0.85
Occipitocervical fusion, n (%)		7 (6)		1 (4)	0.67
Surgical bleeding, mL	112	185 ± 234	26	240 ± 273	0.31
Surgical time, min	114	170 ± 69	24	170 ± 57	0.88
Walking capacity 1 year postoperatively, n					
(Independent / T-cane / walker / inability to walk)		116 / 2 / 1 / 0		0 / 13 / 12 / 2	
[a]Data are the mean ± standard deviation unless otherwise shown.					
[b]Results for denominator of n = 119 (maintained walking capacity group) or n = 27 (deteriorated walking capacity group), unless otherwise indicated by in the column to the left of each of these group results, respectively.					
ASIA American Spinal Injury Association					
*$P < 0.05$					

Table 10
Multivariate logistic regression analysis of associated factors of deteriorated walking capacity 1 year postoperatively (AIS E)

Variables	OR	95% CI	*P*
Age	1.062	0.988–1.141	0.10
Pre-trauma walking capacity	2.308	0.836–6.373	0.11
Total protein	0.532	0.270–1.047	0.07
Hemoglobin	0.735	0.563–0.961	0.02*
OR odds ratio; *CI* confidence interval			
*$P < 0.05$			

Discussion

Based on the present study, we report a 1-year mortality rate of 8% after spinal fusion surgery for cervical fractures in patients 65 years of age or older. In previous reports of cervical spinal fractures in the elderly, the rates of mortality coexistent with a spinal cord injury were 7—53% [2–6]. In our study, 51% of cervical fractures were associated with a spinal cord injury. Thus, our results reflect cervical fractures with a high rate of concomitant spinal cord injury. This can be attributed to the fact that the present study comprised patients who received spinal fusion surgery. Previous reports of mortality associated with cervical spine fractures in the elderly have referred to an in-hospital mortality rate of 8—14% [2–5], and a 1-year mortality rate of 28—29% [6, 7]. Most of those previous reports included both surgical and conservative treatments [2–6]. Although Sander et al. have reported on postsurgical mortality, they noted decompression surgery was included in addition to fusion surgery [7]. In contrast, our study comprised only patients who received spinal fusion surgery for cervical fractures. The best studied relationship between injury type and mortality rate is for hip fractures. The reported 1-year mortality rate after hip fracture in the elderly is 10—30% [10, 11]. Patients with a cervical fracture incur a greater risk of mortality compared with those who sustain a hip fracture [1]. However, we did not demonstrate this phenomenon in the current study.

Our study did show that a higher CCI score, more severe AIS, and a longer surgical time were identified as independent factors associated with increasing 1-year mortality. Previously, whether a greater number of comorbidities was associated with mortality or not is controversial in the elderly with cervical fractures [6, 12]. Based on our results, in patients treated surgically, a poor general condition with a greater number of comorbidities was considered to result in an increase in postoperative complications or poor postoperative recovery, and hence an increased mortality risk. Previously, a neurological deficit has been linked to mortality after a cervical fracture in the elderly [1–3, 6, 13] and mortality has been correlated with the severity of a neurological deficit [13, 14]. The results of our study supported the same finding. Daneshvar et al. demonstrated that an injury at or above C4 had a 7.1 times higher risk of mortality compared with injuries below C4 when spinal cord injuries were related to cervical spine fractures [13]. The logical connection to consider is that the more severe the spinal cord injury, the greater the impact on respiratory muscle function and hence an increased risk for mortality.

We included surgical factors in our investigation because our study comprised patients who were treated surgically. As a result, a longer surgical time was identified as an independent factor associated with increasing 1-year mortality. There are two possible explanations. First, a cervical fracture requiring a long surgical time is typically indicative of severe trauma leading to poor general condition. Second, surgical invasiveness is related to mortality. Some reports indicate that surgical invasiveness for spinal trauma in the acute phase is related to the mortality [6, 15]. Also, greater surgical invasiveness during spinal surgery increases postoperative complications, particularly in the elderly [16]. Our study results showed that the most frequent postoperative complication reported for patients was pneumonia. Bokhari et al. reported that the occurrence of pneumonia is more frequent during conservative treatment than surgical treatment in elderly patients with cervical fractures [17]. In short, there is a possibility that surgical invasiveness gave rise to a decline in the general condition of patients, particularly poor respiratory function leading to mortality. In terms of surgical factors, in our study we were also able to demonstrate that surgical time was a more important factor than surgical approach, surgical bleeding, or number of fused levels.

The rate of deterioration in walking capacity between the time of injury and 1 year postoperatively was 33% in this study. To our knowledge, there are no reports of functional outcomes 1 year after spinal fusion surgery for elderly patients with cervical fractures. With regard to hip fractures in the elderly, the reported 1-year postoperative rate of deterioration in walking capacity is 26–61% [18–20]. Therefore, the rate of deterioration in walking capacity in the elderly with a cervical fracture in our study was comparable to that reported for hip fracture.

A more severe AIS and lower TP and Hb values were identified as independent factors associated with an increased risk of deteriorated walking capacity 1 year postoperatively. Previously, neurological deficits have been related to poor functional outcomes [5]. Our study also demonstrated that the severity of neurological deficits was related to poor functional outcomes for as long as 1 year postoperatively. Reports have indicated that recovery from a spinal cord injury is poor in the elderly population [13]. Moreover, even when neurological function recovered, elderly patients experience difficulties translating improvements in a neurological outcome into functional changes [21]. For these reasons, the severity of a neurological deficit at the time of injury is considered to be strongly associated with a deterioration in walking capacity 1 year postoperatively.

A low level of preoperative Hb has been associated with a poor functional outcome according to some reports of hip fractures in the elderly [22, 23]. Low preoperative Hb values were associated with poor functional outcomes in the elderly with cervical fracture in our study also, particularly in patients without a neurological deficit (an AIS of E). A possible explanation for the relationship between low Hb values and poor functional outcomes is that Hb status could be a marker of an underlying comorbidity [22]. Anemia has been observed to be a risk factor for the frailty phenotype in the elderly [24]. Thus, low Hb values preoperatively could be a reflection of greater frailty associated with a poor functional outcome [22].

Preoperative hypoalbuminemia has been associated with postoperative morbidity and during spinal surgery it has been related to an increase in postoperative complications [25, 26]. In hip fractures in the elderly, hypoalbuminemia or poor nutrition is related to poor functional outcomes [27, 28]. In our study, we were able to demonstrate that low preoperative TP values were associated with a poor functional outcome in the elderly with a cervical fracture, particularly in patients with partial paralysis (an AIS of C/D). Serum TP has traditionally been used as a marker for poor health and nutrition. Currently, we may only postulate how TP affects recovery; for example, potentially via its positive association with complications or its impact on the recovery of neuromuscular function.

In our study, a larger number of fused segments was identified as an independent factor associated with the increased risk of a deteriorated walking capacity 1 year postoperatively in patients with partial paralysis (an AIS of C/D). Previously, whether a larger number of fused segments was associated with a disability and compromises in terms of activities of daily living remains controversial [29, 30]. This study suggested that, particularly in elderly patients with partial paralysis, a limitation in the cervical range of motion due to a larger number of fused segments has a negative impact on walking capacity.

There are some possible limitations in the present study. Because of its retrospective design, there are some missing data. Due to the fact that this was a multicenter study, the indications for surgery, choice of surgical technique, and postoperative treatment were left to the discretion of the surgeon at each hospital. Although the follow-up rate (75%) was high, a selection bias could occur due to the retrospective investigation of only those patients who could be followed-up for 1 year. Because the sample size of the mortality group was small, a further study using a larger sample size is needed to better understand the factors that were associated with mortality after spinal fusion surgery for a cervical fracture in the elderly.

Conclusions

The 1-year rate of mortality after spinal fusion surgery for cervical fracture in patients 65 years of age or older was 8%. A higher CCI score, a more severe AIS, and a longer surgical time were identified as independent factors associated with increasing 1-year mortality. The rate of deterioration in walking capacity between pre-trauma and 1 year postoperatively was 33%. A more severe AIS, as well as lower TP and Hb values, were identified as independent factors associated with an increasing risk of deterioration in walking capacity 1 year postoperatively.

Abbreviations

JASA: Japan Association of Spine Surgeons with Ambition

CCI: Charlson comorbidity index

ASIA: American Spinal Cord Injury Association

AIS: American Spinal Cord Injury Association impairment scale

TP: Total protein

Hb: Hemoglobin

OR: Odds ratio

CI: Confidence interval

Declarations

Acknowledgements

Not applicable

Authors' Contributions

Research conception and design: SK, TS

Data collection: TS, NY, HH, H Tsuchiya, K Ando, H Nakashima, N Segi, KW, SN, K Takeda, T Furuya, A Yunde, S Ikegami, MU, H Suzuki, Y Imajo, T Funayama, FE, A Yamaji, K Hashimoto, Y Onoda, K Kakutani, YK, N Suzuki, K Kato, YT, RH, T Yamada, TH, K Kawaguchi, YH, SS, H Tonomura, MS, HU, H Sawada, H Tominaga, H Tokumoto, TK, Y Iizuka, ET, Y Oshima, H Terai, K Tamai, BO, MM, H Nakajima, KN, KM, GI, K Kiyasu, K Akeda, NT, T Yoshii, MI, S Okada, YA, K Harimaya, HM, KI, S Ohtori, S Imagama, SK

Interpretation of data: SK, TS, NY

Statistical analysis: SK, TS, NY

Drafting the manuscript: TS

Manuscript review: SK, NY

Study supervision: K Ando, KW, T Furuya, TK, GI

Approval of the final manuscript: all the authors listed above

Funding

No funding

Availability of data and materials

The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study has been performed in accordance with the ethical standards in the 1964 Declaration of Helsinki. The institutional review board of the representative facility (Kanazawa University) reviewed and approved this study (No. 3352-1).

All subjects gave written informed consent to participate in the study.

Consent for publication

Not applicable

Competing interests

The authors have no conflicts of interest to declare.

References

1. Cooper Z, Mitchell SL, Lipsitz S, Harris MB, Ayanian JZ, Bernacki RE, et al. Mortality and readmission after cervical fracture from a fall in older adults: comparison with hip fracture using national medicare data. J Am Geriatr Soc 2015 Oct;63(10):2036-42.
2. Asemota AO, Ahmed AK, Purvis TE, Passias PG, Goodwin CR, Sciubba DM. Analysis of cervical spine injuries in elderly patients from 2001 to 2010 using a nationwide database: increasing incidence, overall mortality, and inpatient hospital charges. World Neurosurg 2018 Dec;120:e114-e130.
3. Sokolowski MJ, Jackson AP, Haak MH, Meyer PR Jr, Sokolowski MS. Acute mortality and complications of cervical spine injuries in the elderly at a single tertiary care center. J Spinal Disord Tech 2007 Jul;20(5):352-6.
4. Menendez ME, Ring D, Harris MB, Cha TD. Predicting in-hospital mortality in elderly patients with cervical spine fractures: a comparison of the Charlson and Elixhauser comorbidity measures. Spine (Phila Pa 1976) 2015 Jun 1;40(11):809-15.
5. Malik SA, Murphy M, Connolly P, O'Byrne J. Evaluation of morbidity, mortality and outcome following cervical spine injuries in elderly patients. Eur Spine J 2008 Apr;17(4):585-91.
6. Harris MB, Reichmann WM, Bono CM, Bouchard K, Corbett KL, Warholic N, et al. Mortality in elderly patients after cervical spine fractures. J Bone Joint Surg Am 2010 Mar;92(3):567-74.
7. Sander AL, El Saman A, Delfosse P, Wutzler S, Meier S, Marzi I, et al. Cervical spine fractures in the elderly: morbidity and mortality after operative treatment. Eur J Trauma Emerg Surg 2013 Oct;39(5):469-76.
8. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40(5):373-83.
9. Kirshblum SC, Burns SP, Biering-Sorensen F, Donovan W, Graves DE, Jha A, et al. International standards for neurological classification of spinal cord injury (revised 2011). J Spinal Cord Med 2011 Nov;34(6):535-46.
10. Downey C, Kelly M, Quinlan JF. Changing trends in the mortality rate at 1-year post hip fracture - a systematic review. World J Orthop 2019 Mar 18;10(3):166-175.
11. Shigemoto K, Sawaguchi T, Horii T, Goshima K, Iwai S, Higashikawa T, et al. Multidisciplinary care model for geriatric patients with hip fracture in Japan: 5-year experience. Arch Orthop Trauma Surg 2021 May 20. doi: 10.1007/s00402-021-03933-w. Online ahead of print.
12. Golob JF Jr, Claridge JA, Yowler CJ, Como JJ, Peerless JR. Isolated cervical spine fractures in the elderly: a deadly injury. J Trauma 2008 Feb;64(2):311-5.
13. Daneshvar P, Roffey DM, Brikeet YA, Tsai EC, Bailey CS, Wai EK. Spinal cord injuries related to cervical spine fractures in elderly patients: factors affecting mortality. Spine J 2013 Aug;13(8):862-6.
14. Inglis T, Banaszek D, Rivers CS, Kurban D, Evaniew N, Fallah N, et al. In-Hospital Mortality for the Elderly with Acute Traumatic Spinal Cord Injury. J Neurotrauma 2020 Nov 1;37(21):2332-2342.

15. Kerwin AJ, Frykberg ER, Schinco MA, Griffen MM, Arce CA, Nguyen TQ, et al. The effect of early surgical treatment of traumatic spine injuries on patient mortality. J Trauma 2007 Dec;63(6):1308-13.
16. Nagata K, Shinozaki T, Yamada K, Nakajima K, Nakamoto H, Yamakawa K, et al. A sliding scale to predict postoperative complications undergoing posterior spine surgery. J Orthop Sci 2020 Jul;25(4):545-50.
17. Bokhari AR, Sivakumar B, Sefton A, Lin JL, Smith MM, Gray R, et al. Morbidity and mortality in cervical spine injuries in the elderly. ANZ J Surg 2019 Apr;89(4):412-417.
18. C Cooper. The crippling consequences of fractures and their impact on quality of life. Am J Med 1997 Aug 18;103(2A):12S-17S; discussion 17S-19S.
19. Kitamura S, Hasegawa Y, Suzuki S, Sasaki R, Iwata H, Wingstrand H, et al. Functional outcome after hip fracture in Japan. Clin Orthop Relat Res 1998 Mar;(348):29-36.
20. Moerman S, Mathijssen NM, Tuinebreijer WE, Nelissen RG, Vochteloo AJ. Less than one-third of hip fracture patients return to their prefracture level of instrumental activities of daily living in a prospective cohort study of 480 patients. Geriatr Gerontol Int 2018 Aug;18(8):1244–1248.
21. Jakob W, Wirz M, van Hedel HJ, Dietz V, EM-SCI Study Group. Difficulty of elderly SCI subjects to translate motor recovery–"body function"–into daily living activities. J Neurotrauma 2009 Nov;26(11):2037-44.
22. Sim YE, Sim SD, Seng C, Howe TS, Koh SB, Abdullah HR. Preoperative anemia, functional outcomes, and quality of life after hip fracture surgery. J Am Geriatr Soc 2018 Aug;66(8):1524-1531.
23. Hagino T, Ochiai S, Sato E, Maekawa S, Wako M, Haro H. The relationship between anemia at admission and outcome in patients older than 60 years with hip fracture. J Orthop Traumatol 2009 Sep;10(3):119-22.
24. Ng TP, Feng L, Nyunt MS, Larbi A, Yap KB. Frailty in older persons: multisystem risk factors and the Frailty Risk Index (FRI). J Am Med Dir Assoc 2014 Sep;15(9):635-42.
25. Kim S, McClave SA, Martindale RG, Miller KR, Hurt RT. Hypoalbuminemia and clinical outcomes: What is the mechanism behind the relationship? Am Surg 2017 Nov 1;83(11):1220-7.
26. Adogwa O, Martin JR, Huang K, Verla T, Fatemi P, Thompson P, et al. Preoperative serum albumin level as a predictor of postoperative complication after spine fusion. Spine (Phila Pa 1976) 2014 Aug 15;39(18):1513-9.
27. Sim SD, Sim YE, Tay K, Howe TS, Png MA, Chang CCP, et al. Preoperative hypoalbuminemia: Poor functional outcomes and quality of life after hip fracture surgery. Bone 2021 Feb;143:115567.
28. Lieberman D, Friger M, Lieberman D. Inpatient rehabilitation outcome after hip fracture surgery in elderly patients: a prospective cohort study of 946 patients. Arch Phys Med Rehabil 2006 Feb;87(2):167-71.
29. Lee SH, Lee JC, Tauchi R, Daniel Riew K. Influence of the number of cervical fusion levels on cervical spine motion and health-related quality of life. Spine (Phila Pa 1976) 2016 Apr;41(8):E474-80.

30. Bell KM, Bechara BP, Hartman RA, Shively C, Frazier EC, Lee JY, et al. Influence of number of operated levels and postoperative time on active range of motion following anterior cervical decompression and fusion procedures. Spine (Phila Pa 1976) 2011 Feb 15;36(4):263-8.