

The impact of helicopter emergency medical services and craniocervical traction on the early reduction of cervical spine dislocation in a rural area of Japan

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Abstract

Background

Several clinical and basic studies have shown that an association exists between achieving decompression of the spinal cord within a few hours and neurological recovery, even in patients with complete paralysis due to cervical spine dislocation. This study aimed to clarify the impact of helicopter emergency medical services (HEMS) and craniocervical traction using a halo ring on rapid reduction of lower cervical spine dislocation in rural Japan.

Methods

The success rate of and factors inhibiting closed reduction, time from injury to reduction and functional prognosis of lower cervical spine dislocations treated between July 2012 and January 2020 were retrospectively analysed.

Results

Fourteen patients were transported by HEMS (group H), seven were by ambulances (group A) and two were by themselves. Although the average travelled distance and injury severity score were significantly higher in group H (64.5 km, 28.0) than in group A (24.7 km, 18.6), there was no significant difference in the average time to admission or the time to start craniocervical traction after admission between group H (159.4 min, 52.2 min) and group A (163.6 min, 53.2 min). The urgent traction could be administered for 20 patients. The success rate of closed reduction was 95%, and neurological deterioration following traction was not observed in any cases. The average traction time and weight for reduction were 30.3 min and 16.3 kg, respectively. Patients' body size and fracture-dislocation types did not significantly affect the traction time or weight. The rate of reduction within 4 h after injury was higher in group H (79%) than in group A (33%). Herniated discs were found at dislocation levels in five patients by magnetic resonance imaging scans performed after closed reduction, and all cases of inner fixation were treated via the posterior approach an average of 5.7 days after admission. After these treatment, three of nine AIS A patients recovered the ability to walk, and all the three patients underwent successful closed reduction within 4 h after injury.

Conclusion

HEMS and highly successful closed reduction considerably contributed to the early reduction of cervical spine dislocation and can potentially improve complete paralysis.

Introduction

A widely accepted current concept of the pathophysiology of spinal cord injury is that secondary cord injury involving a cascade of haemorrhagic necrosis occurs after the primary injury due to the mechanical force of the trauma(1). Oedema, ischaemia, inflammation, and apoptosis develop and expand within minutes to hours after injury. Based on these theories, several studies have shown that an association exists between achieving rapid decompression of the spinal and neurological recovery, even in patients with complete paralysis due to cervical spine dislocation(2–7).

However, few institutions and doctors in Miyazaki prefecture can administer urgent spine trauma treatment. This prefecture, which includes several depopulated areas, is located in the southwest of Japan and has a population of 1.17 million people and an area of 6.685 km². Recently, a regional disparity between urban and rural areas in the occurrence of neurological improvement after cervical spine dislocation was reported(8). Moreover, not only in Miyazaki prefecture but also in most medical institutions, it may take more than a few hours to transport patients by ambulance from remote locations, administer primary care, and perform magnetic resonance imaging (MRI) scans and open reduction.

This study aimed to clarify the impact of helicopter emergency medical services (HEMS) and craniocervical traction in achieving rapid reduction of cervical spine dislocation and functional improvement in a medically understaffed rural area in Japan.

Materials And Methods

An emergency and critical care centre and HEMS were established in Miyazaki University Hospital in March 2012. The subjects in this study were patients diagnosed with lower cervical spine (C3-7) dislocation in our institution from March 2012 to January 2020. Other cervical traumas, such as burst fracture, tear-drop fracture, and fracture with spinal ankylosis, were not included in the study. The data collected included age, body weight, height, injury severity score (ISS)(9), fracture-dislocation type, transport method, road distance, traction time and weight for the closed reduction, time from injury to reduction of dislocation, and American Spinal Injury Association Impairment Scale (AIS) grade. The shortest road distances were calculated by Google Maps (URL: www.google.co.jp/maps, Alphabet, Mountain View, CA, USA) using coordinate information (last accessed Mar. 2020). We used Japan Emergency Medical Service data of the injury occurrence places and times, and medical actions were recorded in minutes by our staffs after the requests of dispatch or admission.

The helicopter on stand-by at our institution can dispatch within 5 min after a request and reach a 110-km remote distance within 30 min as previously reported(10, 11). Doctors and nurses board each flight to administer prehospital medicine and determine the facility to which the patient should be transported.

The subjects were admitted directly to the intensive care unit, and computed tomography (CT) scans were performed after the initial treatment. A halo ring was connected after the diagnosis of cervical spine dislocation, and craniocervical traction was performed under X-ray fluoroscopy observation with the patient in neck flexion to make facets unlocked and distracted(4–6). The traction weight was added at increments of 5 kg each up to 30 kg. When reduction was difficult, ketamine was administered for analgesia and sedation to keep the patients awake and monitor neurological changes. Additionally, the halo ring was gently rotated to the dislocation side at the position where the upper and lower articular processes touched or separated (Fig. 1a, b). MRI was performed after closed reduction.

Statistical analyses were performed using SPSS version 21 (IBM, Armonk, NY, USA). Differences in average values were assessed using Student's t-test (Fig. 2a, 2b, 2c and 3b), and these results are presented as the means \pm standard deviations. Pearson's correlation coefficients were assessed in Fig. 3a, and the differences in percentages shown in Fig. 3c were assessed using the Chi-squared test. Ninety-five percent confidence intervals were used to express uncertainty, and $p < 0.05$ was considered statistically significant.

Results

Demographics of the patients. Twenty-three patients were admitted during the study period. The mean age was 67.7 (range 29–91) years, and 19 (83%) of the patients were over 60 years old. Fourteen patients were transported by HEMS (61%, group H), seven patients were transported by ambulances (30%, group A), and two patients transported themselves (9%, group T). Upon admission, the AIS grade was A in nine patients, C in four, D in five, and E in three, and two were in cardio-pulmonary arrest (CPA). The average ISSs of group H, group A, and group T were 30.6, 18.6 and 12.5, respectively (Fig. 2a).

The travelled distance in group H (mean 64.5 km, range 41–134 km) was significantly longer than that in group A (mean 24.7 km, range 3.7–47.9 km) (Fig. 2b), but group H was admitted slightly earlier (mean 159.4 min, ranged 50–885 min) than group A (mean 163.6 min, ranged 67–419 min) (Fig. 2c). Except for delayed transport due to night occurrence (885 min), the average time to admission in group H was 100.0 min. More than 24 h passed between the trauma and admission in both patients in group T.

Mountainous areas account for approximately 90% of the prefecture, and highway passing areas are limited in this region; most highways are single lanes in the eastern area. Fifty percent of the travelled distances in group H were longer than 50 km, and HEMS also covered topographically isolated areas (Fig. 2d). Five of the patients in group H (36%) were admitted via another medical institution as follows: one patient via rendezvous with a helicopter and four patient transfers from a medical institution. The doctors and nurses started prehospital medicine after an average of 25.5 min (range 11–71 min) after the request for HEMS. The reasons why helicopter transport was not chosen in group A were occurrence time (58%), occurrence at a short distance (29%), and a need for urgent cardiopulmonary resuscitation at the closest hospital (14%). Four patients in group A (57%) were transferred from another medical institution.

Closed reduction by craniocervical traction. Although the trauma experienced in group H was significantly more severe than that in group A, craniocervical traction in group H (mean 52.2, range 21–121 min) was started as soon after admission as that in group A (mean 53.2, range 28–90 min). Traction could be performed on 20 of the 23 patients, and their details are shown in Table 1. In two CPA patients and one AIS A patient with unstable vitality, immediate traction was difficult.

The success rate of closed reduction was 95%, and all the reductions were confirmed within 1 h. The average traction time, including ring connection, was 30.3 min (range 7–60 min), and the average traction weight for reduction was 16.3 kg (range 5–30 kg, average 10% (range 3%–19%) of body weight). No significantly strong correlations were observed between the patients' body weight or height and the traction weight or time (Fig. 3a). In addition, there were no significant differences in traction weight and time, ketamine usage or the addition of ring rotation for reduction among the fracture-dislocation types (bilateral/unilateral, complete dislocations/locked facets and with/without facet fractures, Fig. 3b, c). The only closed reduction failure case was two levels of unilateral dislocations (complete dislocation and locked facet) with facet fractures (Table 1).

Eighteen patients had tolerance for MRI after the reduction. Herniated discs were found at dislocation levels in five patients (28%), and the average occupation rate of bulging or herniated discs and haematoma in the canal space was 31.1% (range 12%–48%). All cases of inner fixation and direct decompression of the spinal cord were treated via the posterior approach an average of 5.7 days (range 0–13 days) after admission.

Neurological prognosis. The AIS grade prognoses of the 20 patients who underwent craniocervical traction are shown in Fig. 4. The average follow-up duration of the patients who survived was 613 days (range 159–1381 days). Excluding group T, the rates of reduction within 4, 6 and 8 h after the injuries in nine AIS C-E patients were 44%, 78% and 89%, respectively. The corresponding rates of reduction in the eight AIS A patients, including a closed reduction failure case, were 75%, 75%, and 100%, respectively. Importantly, neurological deterioration following traction was not observed in any cases. Including group T, the AIS grade improved in four of nine AIS C-D patients (44%) immediately after successful reduction, and all nine patients (100%) had improved at the latest follow-up even when reduction was delayed. Three of the seven (43%) AIS A patients had an improved grade immediately after successful reduction, and the reduction in these three patients was confirmed within 4 h after the injuries. One of the three improved to AIS E (normal),

one to D (could walk by themselves), and one to C (could walk with devices and auxiliary). In contrast, two AIS A patients who did not improve neurologically after reduction died within two months of injury.

The rates of reduction within 4, 6 and 8 h were 79%, 86% and 93%, respectively, in group H and 33%, 67% and 100%, respectively, in group A. Although the sample size was small and there were no statistically significant differences (chi-squared test), the outcomes of early reduction within 4–6 h in group H, which included a delayed transport case and a closed reduction failure case, were better than those in group A.

Discussion

Newton reported that when cervical spine dislocations due to rugby play were reduced after more than 4 h, 96% of complete paralysis patients were improved to only AIS grade C or lower(6). Sixty-three percent of complete paralysis cases however, fully recovered following reduction performed within 4 h after injury. Importantly, the 4 h threshold can be applied even to elderly patients that account for over 60% of cervical spinal cord injury patients in Japan(12). In the present study, all AIS A patients who recovered the ability to walk were older than 60 years old. According to some basic and clinical research, the neurological deficit caused by secondary cord injury has been shown to be time-dependent, and the pathological changes of secondary injury, such as oedema and ischaemia, are believed to be initiated and expand within 6 to 24 h of injury(1, 3, 8). In addition, in animal models, only those in which compression of the spinal cord was released within 6 h achieved neurological recovery(2). Therefore, although decompression of the spinal cord performed at more than 24 or 72 h after injury have in some studies been defined as early procedures(3, 7), we define these as delayed procedures. A Japanese cohort study also showed that 27% of complete paralysis patients had conditions that recovered to AIS C-E only when cervical spine dislocations were reduced within 6 h, and there was no significant difference in the recovery rate between the within-4 h group and the within-6 h group(5). Thus, although we attempted to achieve reduction within 4 h, 6 h is recognized as the gold standard period for achieving favourable recovery from complete paralysis.

In our study, closed reduction was started approximately 1 h after admission, and all such procedures were completed within 1 h. The achieved performance was as favourable as that in some previous reports in which closed reduction was performed within 2 h after admission(4, 13). Then, considering that reduction should be performed within 4 h of injury, as described above, patient transport within at least 2 h after injury is desirable. Regarding admission within 2 h after injury, HEMS significantly reduced the time required for patient transport. HEMS has been practically operated in Japan since 2001 after the popularization of the system in Western countries(14, 15). As the system improved survival after major trauma(16) and increased the indication for thrombolytic therapy in cerebral infarction(17), the application of prehospital medicine beginning early after injury and rapid transport notably contributed to the early reduction of cervical spine dislocations and neurological recovery in the present study. Helicopter transport has been reported to have an impact on rapid admission for distances greater than 16 km(18); moreover, it reduces regional differences in medical care(8), such as in rural Japan, where limited hospitals can be consolidated(10, 11, 19).

According to a review of closed reduction in cervical spine dislocations, the success rate was approximately 80% in more than 1,200 patients, while the permanent neurological complication rate was less than 1%(4). The treatment of transient injury with closed reduction was also reported to be rare (2–4%). In the present study, closed reduction was also highly successful, and no neurological deterioration was reported. The maximum traction weight for reduction has been reported to be 43.1 kg to 172.6 kg, or 50%–80% of the patient's body weight(4, 6, 13, 20, 21). However, the average traction weight used for reduction in our study was 10% of the patient's body weight, and 30 kg was enough for the maximum weight. Moreover, our technique was not substantially affected by patient body size or fracture-dislocation type. Ketamine and rotation of the halo ring might help prevent the need for more traction weight and neurological deterioration caused by overdistraction of the spinal cord(8, 22). For stability and the dispersion of traction load in the skull, we used a halo ring with multiple pinning fixation. After reduction, the halo vest also served as a damage-controlling external fixation device during the period when the patient waited to undergo surgery until the general complications improved.

In this study, MRI exams were performed after the closed reduction of cervical spine dislocation to determine the surgical procedure and range. Regarding the prevalence of disc disruption, a postreduction MRI study of 80 patients treated with closed reduction found herniated or bulging disks in 46% of these patients(13). However, the prevalence was reported to be 55% in 24 patients in a separate prerelief MRI study(23). Moreover, monitored by frequent MRI during closed reduction, all herniated discs returned towards the disc space without any neurological deterioration(20). Importantly, there is Class III medial evidence of early closed reduction for neurological improvement(4), although evidence supporting the use of prerelief MRI findings for recovery is lacking. To prevent delayed reduction and transport of a patient with unstable paralysis and vitality due to cervical spine dislocation, we performed postreduction MRI.

The present study has several limitations including its observational design. It is a retrospective study of small sample size, and detailed comparison of the prognosis between patient transport systems or times from injury to reduction are lacking. But it is ethically difficult to randomize the systems and times. Therefore, after development of emergency medical system and dissemination of the closed reduction methods in our area, a cohort study premised on early dislocation reduction is desirable for the further study.

Conclusion

The reduction of cervical spine dislocations within 4–6 h injury, which can improve even complete paralysis in elderly patients, can be achieved in medically understaffed rural areas using a strategy including HEMS, craniocervical traction using a halo ring and postreduction MRI. Moreover, this strategy may also reduce regional disparities in the prognosis of cervical dislocation.

Abbreviations

HEMS
Helicopter emergency medical services
MRI
Magnetic resonance imaging
ISS
Injury severity score
AIS
American Spinal Injury Association Impairment Scale
CT
Computed tomography
CPA
Cardio-pulmonary arrest

Declarations

Ethics approval

Our study was approved by the institutional ethics board (no. 2019-062).

Consent for participation and publication

Information regarding the conduct of research including objectives was disclosed and the subjects were provided an opportunity to refuse inclusion in the research.

Availability of data and material

The datasets generated and analysed in the current study are available from the corresponding author upon reasonable request.

Competing of interest

The authors have no competing financial or non-financial interests.

Funding

No funds were received in support of this work.

Authors' contributions

EC designed the study conception. TN, KH, SK and HH contributed to the acquisition and establishment of the system using helicopter emergency medical services and craniocervical traction for the rapid reduction of cervical spine dislocation. HO and DL drafted the manuscript. KK, SI and TK collected data on the passage of time from medical records, DL analysed the data, and YY interpret data and the manuscript.

Acknowledgements

Not applicable

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Tables

Table 1 Characteristics of the patients who underwent craniocervical traction

The case numbers are listed in chronological order. Bil., lt., rt., up., and low. represents bilateral, left, right, upper articular process, and lower articular process, respectively.

Case number	Age (years old)	Sex	Body weight (kg)	Body height (cm)	Dislocation level	Laterality	Complete dislocation /locked facet	Facet fracture	Ketamine	Ring rotation	Traction time for reduction (min)	Traction weight for reduction (kg)
1	77	M	54.8	164	C5/6	left	Complete	None	-	-	15	5
2	63	M	60.6	166	C6/7	left	Complete	C6 lt. up.	-	-	21	5
3	81	M	60.8	163	C5/6	left	Complete	None	-	-	15	15
4	37	M	48.6	170	C6/7, C7/Th1	C6/7 left C7/Th1 right	C6/7 Complete C7/Th1 Locked facet	C6 bil. low. C7 lt. up., low.	Used	-	failure	failure
5	80	F	37.5	148	C6/7	right	Locked facet	C7 bil. low.	-	-	60	15
6	74	M	60.3	158	C5/6	bilateral	Locked facet	C5 rt. low.	-	to left	15	15
7	75	M	64.6	160	C4/5	bilateral	Locked facet	None	-	-	15	5
8	67	M	74.5	180	C5/6	bilateral	Locked facet	None	-	-	7	5
9	85	M	53.5	162	C3/4	bilateral	Complete	None	-	-	49	5
10	29	M	67.9	180	C6/7	left	Complete	C7 lt. up.	Used	-	48	20
11	47	M	48.3	180	C6/7	right	Complete	C7 rt. up.	-	to right	38	20
12	85	M	53.5	157	C6/7	right	Locked facet	C7 bil. low.	Used	to right	40	30
13	74	M	57.1	157	C5/6	left	Locked facet	C6 lt. up.	Used	to left	32	25
14	61	M	55.8	170	C6/7	left	Complete	C6 lt. up.	Used	to left	33	25
15	48	M	95.8	176	C5/6	left	Complete	C5 lt. low.	-	to left	42	15
16	61	M	55.8	170	C5/6	right	Locked facet	C5 lt. low.	Used	to right	32	25
17	76	M	48.3	156	C5/6	left	Complete	None	-	-	25	15
18	82	M	55.1	158	C5/6	bilateral	Complete	None	Used	to right	32	25
19	74	F	50.9	147	C6/7	bilateral	Locked facet	None	Used	-	24	20
20	91	M	55	162	C5/6	left	Complete	None	Used	-	21	20

Figures

Figure 1

a



b

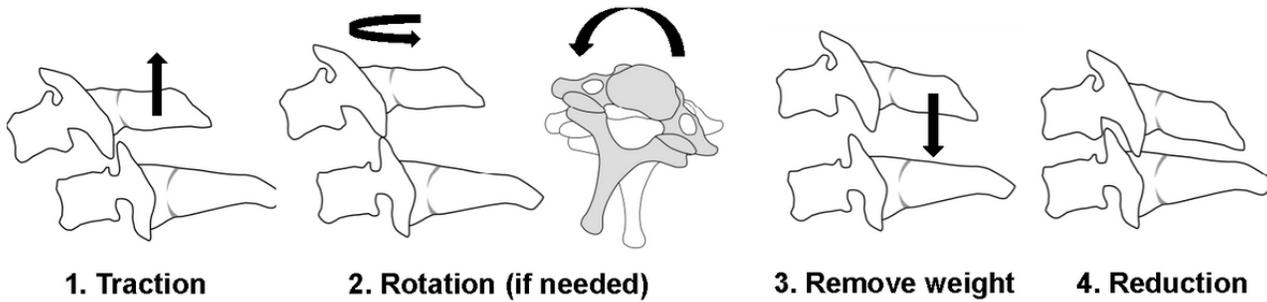


Figure 1

The procedure used in craniocervical traction (a) Photo of craniocervical traction using a halo ring under X-ray fluoroscopy observation. (b) Five kg of each weight was added at intervals until 30 kg was reached. If needed, the halo ring was gently rotated to the dislocation side at the position where the upper and lower articular processes were just touching or separated.

Figure 2

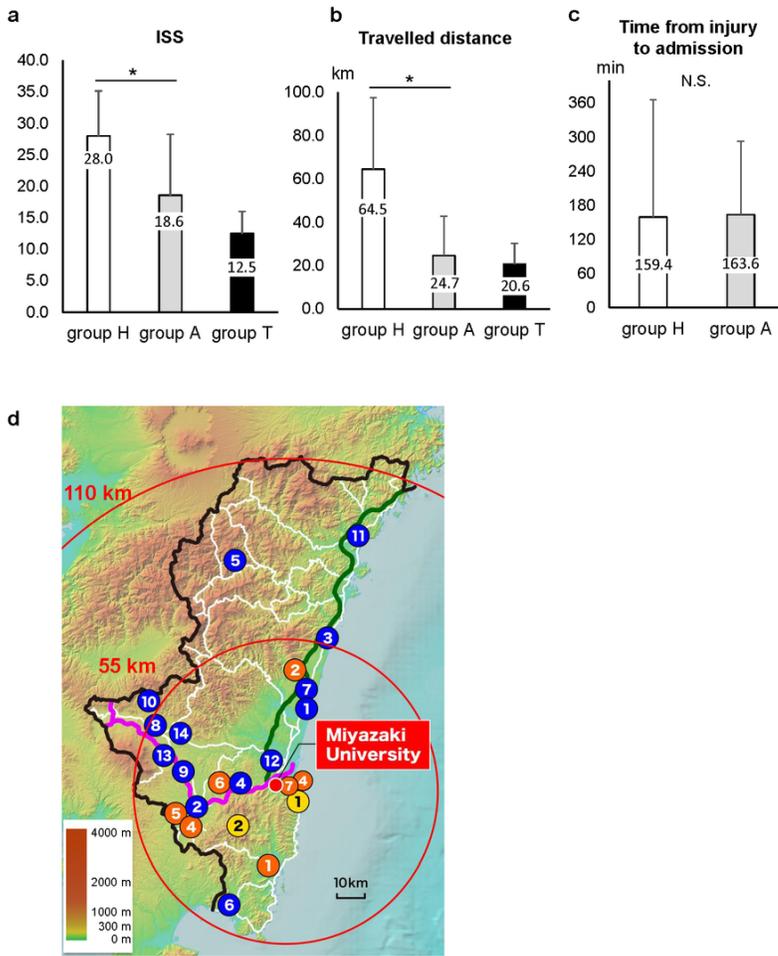


Figure 2
 The demographics of the patients (a) Injury severity score, (b) travelled distance and (c) time from injury to admission were compared among group H (n=14), group A (n=7) and group T (n=2). * p<0.05 and N.S. indicates not significant. (d) The geographic locations at which the injuries occurred are shown on a map of Miyazaki prefecture (surrounded by a black line) obtained from the homepage of the Geospatial Information Authority of Japan. Blue, red, and yellow points represent cases in group H, group A, and group T, respectively. Purple and green lines represent two- and single-lane highways, respectively.

Figure 3

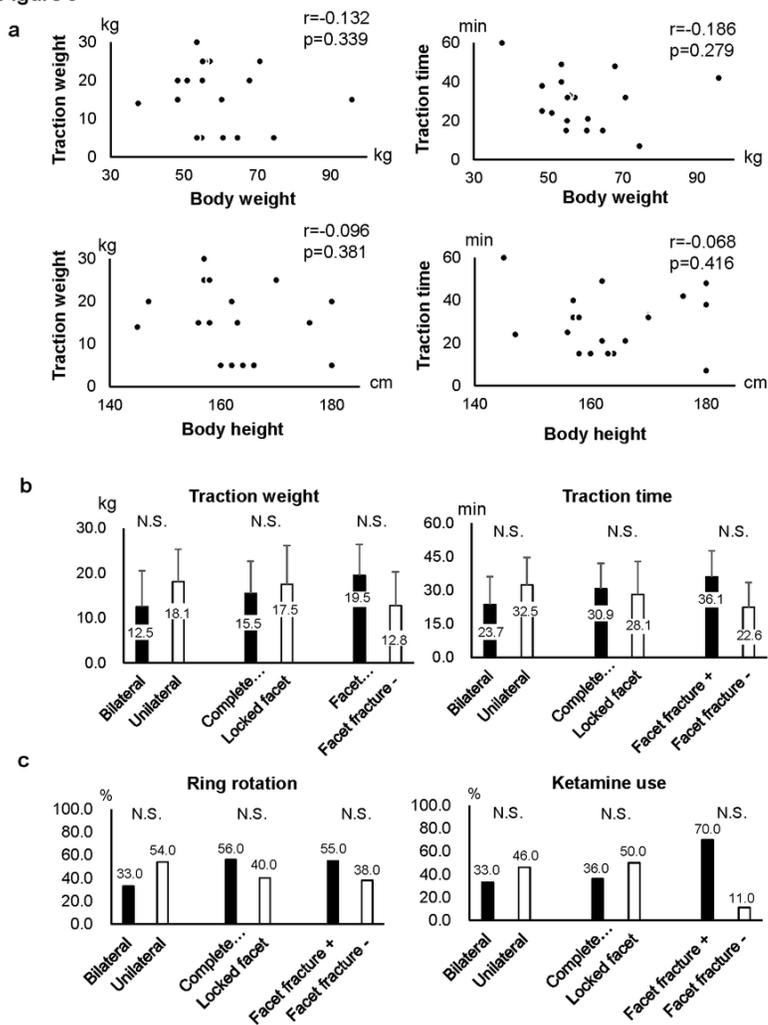


Figure 3

Analysis of factors that inhibit closed reduction (a) Correlation graphs for the relationships between patient body weight or height and traction weight or time. (b) Traction weight and time and (c) the percentages of cases with the addition of halo ring rotation and ketamine use were compared among the fracture-dislocation types (6 bilateral/13 unilateral, 11 complete dislocations/8 locked facets and 10 with/9 without facet fractures). N.S. indicates not significant.

Figure 4

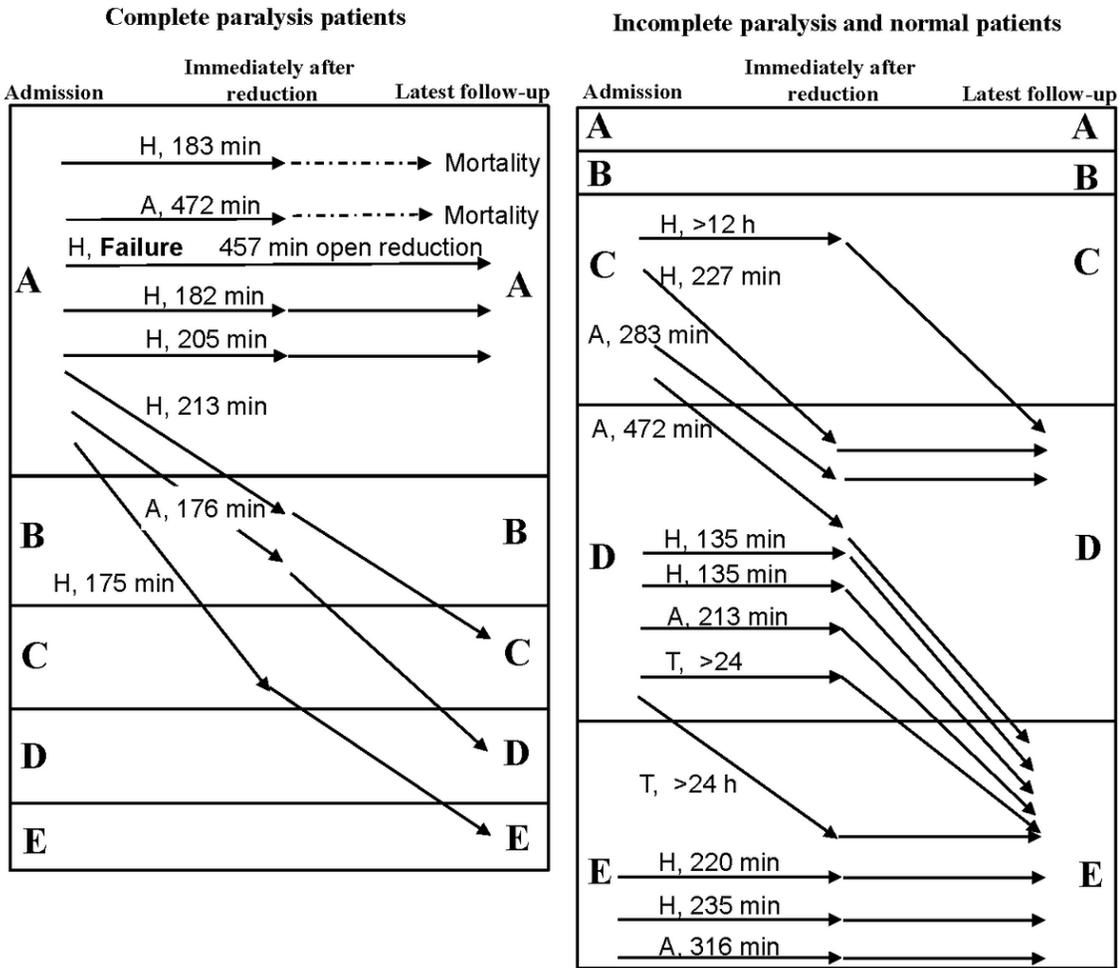


Figure 4

Prognosis according to the American Spinal Injury Association Impairment Scale H, A, and the time in the squares indicate group H, group A, and the time from injury to the confirmation of closed reduction, respectively.