Risk of early closed reduction in cervical spine subluxation injuries

GERALD A. GRANT, M.D., SOHAIL K. MIRZA, M.D., JENS R. CHAPMAN, M.D., H. RICHARD WINN, M.D., DAVID W. NEWELL, M.D., DOLORS T. JONES, R.N., AND M. SEAN GRADY, M.D.

Departments of Neurological Surgery and Orthopedic Surgery, University of Washington Medical Center, Seattle, Washington

Object. The authors retrospectively reviewed 121 patients with traumatic cervical spine injuries to determine the risk of neurological deterioration following early closed reduction.

Methods. After excluding minor fractures and injuries without subluxation, the medical records and imaging studies (computerized tomography and magnetic resonance [MR] images) of 82 patients with bilateral and unilateral locked facet dislocations, burst fractures, extension injuries, or miscellaneous cervical fractures with subluxation were reviewed. Disc injury was defined on MR imaging as the presence of herniation or disruption: a herniation was described as deforming the thecal sac or nerve roots, and a disruption was defined as a disc with high T_2-weighted signal characteristics in a widened disc space. Fifty-eight percent of patients presented with complete or incomplete spinal cord injuries. Thirteen percent of patients presented with a cervical radiculopathy, 22% were intact, and 9% had only transient neurological deficits in the field.

Early, rapid closed reduction, using serial plain radiographs or fluoroscopy and Gardner–Wells craniocervical traction, was achieved in 97.6% of patients. In two patients (2.4%) closed reduction failed and they underwent emergency open surgical reduction. The average time to achieve closed reduction was 2.1 ± 0.24 hours (standard error of the mean).

The incidence of disc herniation and disruption in the 80 patients who underwent postreduction MR imaging was 22% and 24%, respectively. However, the presence of disc herniation or disruption did not affect the degree of neurological recovery, as measured by American Spinal Injury Association motor score and the Frankel scale following early closed reduction. Only one (1.3%) of 80 patients deteriorated, but that occurred more than 6 hours following closed reduction.

Conclusions. Although disc herniation and disruption can occur following all types of traumatic cervical fracture subluxations, the incidence of neurological deterioration following closed reduction in these patients is rare. The authors recommend early closed reduction in patients presenting with significant motor deficits without prior MR imaging.

KEY WORDS • cervical spine • magnetic resonance imaging • disc herniation • closed reduction

THE proper treatment of acute traumatic cervical spine subluxation injuries remains controversial. Clinically significant disc herniation occurs in association with cervical trauma; however, the exact incidence of acute disc herniation remains unknown. Because the benefit of aggressive spinal cord decompression after occurrence of neurological deficit has been debated, no strict guidelines exist in the management of these acute injuries with regard to the timing of closed reduction and prioritization of imaging studies such as magnetic resonance (MR) imaging and computerized tomography (CT) scanning.

Disc disruption can occur in the setting of intervertebral subluxation. Rupture of the posterior longitudinal ligament and posterior annulus can allow extrusion of the disc and cause spinal cord compression.[12] Using CT myelography, reported rates of disc herniation in the setting of cervical trauma have been fewer than 5% of patients; however, the reported incidence of traumatic disc herniation detected on MR imaging ranges from 15 to 54%.[5,7,10,11,13]

Reduction of a dislocation of the cervical spine potentially increases the diameter of the spinal canal at the level of injury and decompresses the spinal cord. However, it has also been theorized that patients with cervical spine subluxation injuries may suffer neurological deterioration following closed reduction in the presence of an associated herniated disc at the level of injury.[3,9,12] We present our experience with 121 patients admitted with cervical spine subluxation injuries and address the incidence of cervical disc injury and the risk of early closed reduction in these patients.

Clinical Material and Methods

Patient Population

This study is a retrospective review of 121 eligible patients admitted to Harborview Medical Center in Seattle, Washington, from July 1, 1994 to August 1, 1997, with acute traumatic lower cervical spine injuries (C3–7).

TABLE 1

Inclusion and exclusion criteria applied to 121 patients presenting at Harborview Medical Center with acute spinal cord injuries

Inclusion Criteria	Exclusion Criteria
cervical spine injury (C3–7)	minor fracture (lamina, spinous process fractures)
malalignment	gunshot wound
examinable	no malalignment
	comminuted skull fracture

Inclusion and exclusion criteria were applied (Table 1). All 121 patients were examinable at admission to the emergency room. Twenty-two patients who suffered gunshot wounds or minor fractures (that is, lamina or spinous process fractures) were excluded from the review as were 17 additional patients who had acceptable alignment of the spinal column (< 3.5 mm subluxation) and no evidence of spinal cord compression at presentation. The medical records and imaging studies of the remaining 82 patients were retrospectively reviewed.

The patient population consisted of 63 men and 19 women, with an average age of 42 years. The skeletal injury was classified using plain x-ray films and CT scans according to the scheme of Ducker, et al.,[4] as unilateral and bilateral facet dislocations, burst fracture, extension injury, or miscellaneous cervical fractures with subluxation (that is, pedicle fracture).

Treatment Protocol

All patients were treated immediately at presentation to the emergency room according to Advanced Trauma Life Support guidelines following spinal immobilization. All patients received methylprednisolone according to the guidelines outlined in the National Acute Spinal Cord Injury study.[2] Serial detailed clinical examinations were performed by senior neurosurgical house officers by using the American Spinal Injury Association (ASIA) motor scale[1] and the Frankel scale[6] to assess the degree of neurological impairment. Craniocervical traction was applied in all patients with Gardner–Wells tongs (Codman and Shurtleff, Inc., Randolph, MA). There were no patients with concomitant comminuted skull fractures, because Gardner–Wells tong application is contraindicated in these patients. Using sequential weight applications, we attempted immediate reduction to improve the spinal alignment and reduce cord compression. Traction weight was increased in 5- to 10-lb increments every 5 minutes (up to 80% of the patient's body weight), and sequential neurological examinations and plain x-ray films were used to monitor spinal alignment. Muscle relaxants were used as adjuncts to achieve closed reduction in 29 (35%) of 82 patients. No manipulative traction was performed. Serial x-ray films or fluoroscopy were used to monitor spinal alignment between weight applications. Open reduction was performed in cases when closed reduction was unsuccessful. Contraindications to continuing closed reduction procedures included the presence of intervertebral distraction up to one and one-half times the baseline disc height, neurological worsening, or intense pain during traction. The ASIA motor and Frankel grades were determined on admission to the emergency room, and at 6 and 24 hours
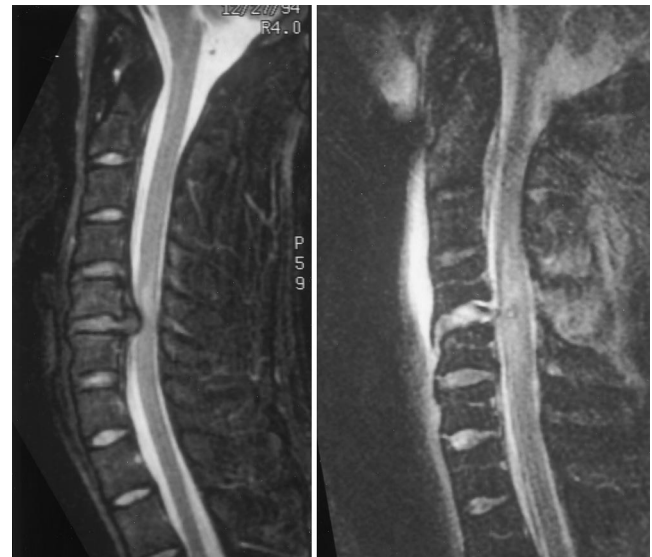

FIG. 1. Midline sagittal MR images of the cervical spine revealing *(left)* disc herniation at the C5–6 level with thecal sac compression (TR 4210, TE 68) and *(right)* disc disruption at the C4–5 level without thecal sac compression (TR 4137, TE 68).

postreduction. Once closed reduction was achieved, the traction weight was reduced.

Magnetic Resonance Imaging

We obtained cervical MR images (1.5 tesla) using a spin–echo sequence with repetition/echo times of 600/11 msec for T_1-weighted and 4864/68 msec for T_2-weighted images within 24 hours following closed reduction. The T_1-weighted images provided anatomical detail of the spinal cord itself. The T_2-weighted images were used to detect disc herniation, ligamentous disruption, spinal cord edema, or acute hemorrhage. Disc injury was defined on MR images as the presence of herniation or disruption. Herniation was defined as an extruded disc that deformed the thecal sac or nerve roots (Fig. 1). A disruption was defined as a disc with high T_2-weighted signal characteristics in a widened disc space but without herniation into the spinal canal (Fig. 2). All images were reviewed retrospectively by the authors, who were blinded to the patients' names and history.

Statistical Analysis

All statistical analyses were performed using SPSS (version 6.1, SPSS Inc., Chicago, IL). Several dependent factors were cross-tabulated with classifications of the disc injury and fracture type to calculate the Pearson correlation coefficient. The ASIA motor scores are presented as mean $\pm$ standard error of the mean and were compared pre- and postreduction by using a paired samples t-test. A probability value of less than 0.05 was considered statistically significant.

Results

Patient Demographics

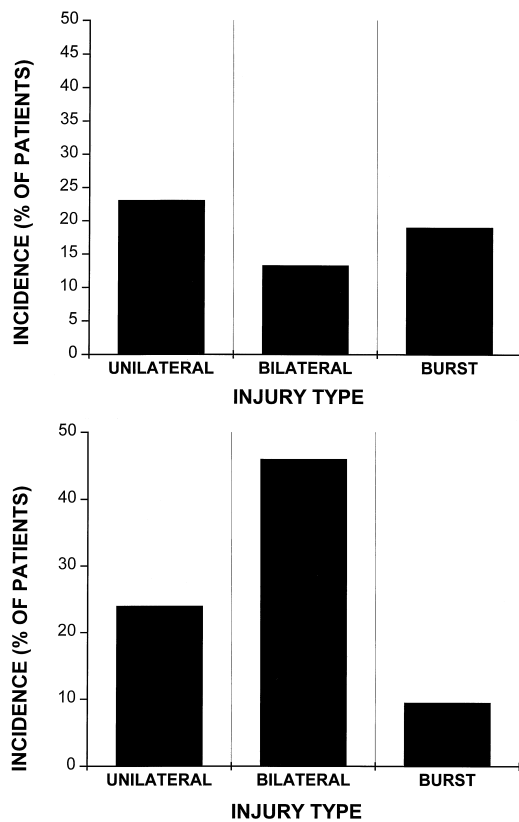All 82 patients reviewed had sustained cervical spine

FIG. 2. Graphs displaying the incidence of disc herniation *(upper)* and disruption *(lower)* classified by injury type.

subluxation injuries. Patients were awake and examinable in the emergency room. The mechanisms of injury were motor vehicle accident (50%), fall from a height (22%), sports-related event (16%), or other (12%). Forty-one (50%) of 82 patients presented with either a unilateral (26 patients [32%]) or bilateral (15 patients [18%]) facet dislocation injury. Of 82 patients, 21 (26%) presented with compressive burst fractures, nine (11%) with extension injuries, and 11 (13%) with miscellaneous cervical fractures with subluxation (Table 2).

Closed Reduction

Immediate, rapid closed reduction was successful in 80 (97.6%) of 82 patients. The average time to achieve closed reduction was 2.1 ± 0.24 hours from the time of arrival in the emergency room. The average traction weight applied was $37 \pm 4\%$ of body weight, ranging from 4 to 80%. The closed reduction procedure failed to realign the spinal column adequately and decompress the spinal cord in two (2.4%) of 82 patients despite maximum weight application. Neither of these two patients suffered neurological deterioration as a result of attempted closed reduction, and both patients underwent emergency open surgical reduction.

Magnetic Resonance Imaging

A postreduction MR image was obtained within 24 hours of reduction in 76 of 82 patients. The incidence of

disc injury at the level of the fracture subluxation was 46% (35 of 76 patients), which includes disc herniation and disruption (Fig. 2). The overall incidence of disc herniation was 22% (17 of 76 patients). There was no significant difference in the incidence of disc herniation in patients with unilateral (five [23%] of 22) or bilateral (two [13%] of 15) facet dislocation injuries. Moreover, the incidence of disc disruption in all 76 patients was 24% (18 patients). The presence of a disc injury (herniation or disruption) did not correlate with the mechanism of injury ($p = 0.110$).

The incidence of disc injury was significantly more common in older patients (defined as > 55 years of age; $p = 0.013$). A spinal cord contusion was diagnosed on MR imaging by the presence of increased T_2-weighted signal intensity within the spinal cord parenchyma at the level of injury. The presence of a disc herniation or disruption significantly correlated with the presence of a spinal cord contusion on MR imaging ($p = 0.0006$).

Neurological Status

The majority of patients presented with complete or incomplete spinal cord injuries. Of the 82 patients in this study, 30% (25 patients) presented with complete and 26% (21 patients) with incomplete spinal cord injuries. Thirteen percent (11 patients) presented with a cervical radiculopathy, and 9% (seven patients) had only transient neurological deficits in the field, which recovered by the time of emergency room admission. The remaining 18 patients (22%) were intact (Table 3).

Neurological recovery significantly improved by 24 hours following the closed reduction procedure. The average ASIA motor score prior to reduction was 54.6 ± 5.2 compared with 59.3 ± 4.9 following reduction ($p = 0.0001$). The average motor score significantly improved in both groups of patients with complete and incomplete spinal cord injuries (Fig. 3). The patients presenting with a complete Frankel A spinal cord injury improved from

TABLE 2
Classification of skeletal injury in 82 patients undergoing early closed reduction

Skeletal Injury Type	No. of Patients (%)
unilat facet dislocation	26 (32)
bilat facet dislocation	15 (18)
compressive burst fracture	21 (26)
extension injury	9 (11)
miscellaneous fracture	11 (13)

TABLE 3
Classification of neurological injury in 82 patients undergoing early closed reduction

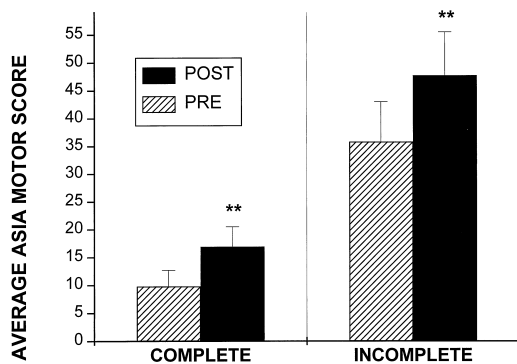| Injury Type	No. of Patients (%)
complete	25 (30)
incomplete	21 (26)
radiculopathy	11 (13)
transient	7 (9)
intact	18 (22)

FIG. 3. Graph showing the average improvement in ASIA motor score following closed reduction in complete and incomplete spinal cord–injured patients.

TABLE 4
Summary of outcomes in patients treated for cervical spine subluxation injuries

Outcome	Percentage of Patients
successful closed reduction*	97.6
disc herniation	22.0
disc disruption	24.0
neurological deterioration	1.3

* Time to reduction was 2.1 ± 0.24 hours (standard error).

9.8 ± 2.9 to 16.9 ± 3.6 (p = 0.001). The patients presenting with an incomplete injury improved from 35.8 ± 7.2 to 47.7 ± 7.8 (p = 0.005). The presence of disc herniation or disruption did not affect the degree of neurological recovery following early closed reduction, as assessed by the ASIA motor score and the Frankel score (p = 0.34).

Only one (1.3%) of 80 patients deteriorated following immediate closed reduction (Table 4). This patient was a 50-year-old man who presented with a C-5 burst fracture with subluxation. He deteriorated by four ASIA motor score points more than 6 hours postreduction (Fig. 4). However, another patient, a 22-year-old man, who suffered a Frankel B spinal cord injury secondary to a unilateral facet fracture dislocation, underwent prereduction MR imaging at an outside institution prior to arrival in our trauma center. This MR image revealed a herniated disc at the C5–6 level, which was reduced following closed reduction on repeated imaging (Fig. 5).

Discussion

Our review of the traumatic cervical spine injuries over the last 3 years indicates that immediate closed reduction is a safe procedure in awake, examinable patients. Although disc herniation and disruption can occur following all types of traumatic cervical fracture subluxations, the incidence of neurological deterioration following closed reduction in these patients is rare.

Incidence of Disc Injury

Magnetic resonance imaging is a valuable tool in the evaluation of acute spinal cord–injured patients with greater sensitivity and specificity than CT myelography.[8] Furthermore, it provides imaging of the spinal cord and can therefore help surgeons in outlining treatment plans for patients with cervical spine injuries.

Magnetic resonance imaging revealed acute disc injury (herniation or disruption) in 46% of the patients in our series. Disc herniation frequently occurred not only in patients with unilateral and bilateral facet dislocation injuries but also in patients with compressive burst injuries. We obtain postreduction MR images to determine the definitive treatment in patients with acute cervical spine injuries. However, because the imaging is performed after closed reduction, we are unable to ascertain whether retropulsion of the disc was caused by the initial trauma or by the closed reduction itself.

Although a traumatic disc herniation could theoretically increase spinal cord compression following closed reduction,[3] our experience does not show this to be a clinically significant concern. Irrespective of the presence of a disc injury, the incidence of neurological deterioration following closed reduction was rare in our series.

We also noted reversal of a disc herniation with closed reduction. In one such patient who achieved reversal, a cervical MR image was obtained at an outside institution, demonstrating a disc herniation. On repeated imaging postreduction, the herniated disc had resolved and resembled a disc disruption. In our series, the average incidence of disc disruption was actually greater than that of disc herniation. Therefore, many of the patients with a disc disruption on their postreduction MR images may have had undetected herniated discs prior to reduction, which then reduced following closed reduction.

Timing of Closed Reduction

All patients in this series underwent attempted closed reduction procedures with axial craniocervical traction using Gardner–Wells tongs according to a standard protocol outlined earlier. The goal of closed reduction was to restore anatomical alignment of the spine as quickly as possible after initial resuscitation in the emergency room. In our series, no manipulative traction was performed in these patients, and one-third of patients required the administration of muscle relaxants as an adjunct to achieve closed reduction. Increasing weight was applied in these patients in 5- to 10-lb increments, occasionally up to 80% of body weight. Between each addition of weight, a motor and sensory neurological examination was performed. The maximum amount of weight applied was limited by intervertebral distraction or neurological deterioration. The end point chosen for this study was either reduction of the dislocation or subluxation, evidence of excessive intervertebral distraction of the cervical spine, or risk of Gardner–Wells tong dislodgment due to excessive traction weight. The Gardner–Wells tongs did not pull out in any of the patients during closed reduction. Use of fluoroscopy is extremely valuable in monitoring spinal alignment during the closed reduction and, in our institution, was often much more time efficient than obtaining portable serial x-ray films.

Of our patients, 97.6% underwent successful closed reduction within a mean of 2.1 hours of admission to the emergency room. In our institution, a longer period of

FIG. 4. Right sagittal MR image (TR 4500, TE 90) of the cervical spine showing a disc herniation at the C5–6 level with spinal cord compression and associated spinal cord edema at the level of injury.

FIG. 5. Midline sagittal MR images of the cervical spine showing *(left)* disc extrusion into the spinal canal and posterior to the C-5 body with associated spinal cord edema (TR 4705, TE 34) and *(right)* reduction of the disc herniation following closed reduction and persistent spinal cord edema extending from C4–7 (TR 6101, TE 34).

time is required on average to achieve open surgical reduction. Further diagnostic workup would also increase the time the spinal cord is mechanically deformed by skeletal malalignment. In addition to pharmacological treatment in patients with spinal cord injury, we believe that urgent mechanical decompression of the spinal cord is critical to maximize the potential for neurological recovery. This approach applies only to patients with significant motor deficits. However, the benefits of early decompression in cervical spinal cord injury have not yet been proven in a prospective, randomized study. Time is not as great a concern in patients who are neurologically intact. However, closed reduction may still decrease the risk of iatrogenic neurological deterioration during hospitalization, particularly if the patient with a highly unstable cervical injury is transferred back and forth for diagnostic studies.

Risk of Closed Reduction

Several authors have recommended obtaining imaging studies prior to closed reduction. Eismont, et al.,[5] have reported on six cases of neurological deterioration after reduction of cervical spine dislocation injuries secondary to extrusion of an intervertebral disc. They strongly advocated performing imaging studies prior to reduction in any patient with a neurological deficit to assess the injured disc at the level of injury. If disc herniation was present, they recommended anterior discectomy prior to reduction. Rizzolo, et al.,[11] have reported MR imaging findings of disc disruption in 23 of 55 patients with cervical spine injuries and recommended obtaining an MR image prior to treatment to assess this problem in patients with a deteriorating neurological status or an incomplete cord injury. Ho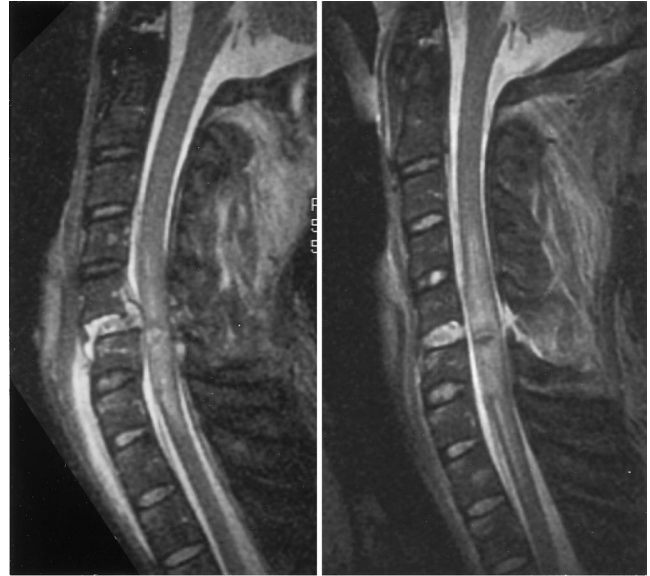wever, the report showed no correlation of the presence of disc injury with neurological injury, age, or sex of the patients. Doran, et al.,[3] have reported on 14 patients with bilateral facet dislocations, 10 of whom had associated disc herniation. They recommended performing MR imaging prior to reduction and anterior discectomy if the imaging study demonstrated disc herniation. No evidence was presented to indicate a worse outcome with closed reduction or a better result with anterior discectomy and fusion.

In our study, one (1.3%) of 80 patients deteriorated by four ASIA motor points but did so more than 6 hours following closed reduction. This patient was found to have a right lateral disc herniation on postreduction MR imaging. Although the neurological deterioration was also lateralized to the right, this change in motor score was minor and most likely was a result of a cervical radicular compromise and not due to spinal cord compression. Furthermore, because deterioration occurred so many hours after closed reduction, we conclude it was not related to the procedure.

Complete Compared With Incomplete Deficits

The goal of skeletal traction for closed reduction is to alleviate spinal cord compression. Obtaining an MR image prior to closed reduction adds a significant time delay at most institutions and may place the patient at added risk prior to stabilization measures. Consequently, we do not delay closed reduction in a patient with a cervical fracture dislocation who presents with a complete motor deficit. We also advocate immediate closed reduction for patients with incomplete spinal cord injuries who present with significant motor deficits. In contrast, a patient with intact neurological function or a cervical radiculopathy and per-

sistent malalignment of the cervical spine presents a very challenging clinical dilemma. Neurological deterioration is very much the overriding concern in such a patient, and further diagnostic measures, such as obtaining an MR image, may be pursued prior to reduction. In our series, none of the 22 intact patients showed any neurological deterioration following closed reduction.

Conclusions

Rapid closed reduction of cervical spine subluxation injuries by using traction is safe and effective. In our series, closed reduction was successfully performed within a few hours of injury. Although a disc injury documented by MR imaging is associated with these traumatic cervical spine injuries, the risk of neurological deterioration following closed reduction is rare.

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