

Initial Closed Reduction of Cervical Spinal Fracture-Dislocation Injuries

Daniel E. Gelb, MD*

Mark N. Hadley, MD‡

Bizhan Aarabi, MD, FRCSC

Sanjay S. Dhall, MD¶

R. John Hurlbert, MD, PhD,
FRCSC||

Curtis J. Rozzelle, MD#

Timothy C. Ryken, MD, MS**

Nicholas Theodore, MD‡‡

Beverly C. Walters, MD, MSc,
FRCSC‡‡‡

*Department of Orthopaedics and;
§Department of Neurosurgery, University of Maryland, Baltimore, Maryland; ‡Division of Neurological Surgery and; #Division of Neurological Surgery, Children's Hospital of Alabama, University of Alabama at Birmingham, Birmingham, Alabama; ¶Department of Neurosurgery, Emory University, Atlanta, Georgia; ||Department of Clinical Neurosciences, University of Calgary Spine Program, Faculty of Medicine, University of Calgary, Calgary, Alberta, Canada; **Iowa Spine & Brain Institute, University of Iowa, Waterloo/Iowa City, Iowa; ‡‡Division of Neurological Surgery, Barrow Neurological Institute, Phoenix, Arizona; ‡‡‡Department of Neurosciences, Inova Health System, Falls Church, Virginia

Correspondence:

Mark N. Hadley, MD, FACS, UAB
Division of Neurological Surgery,
510 – 20th St S, FOT 1030,
Birmingham, AL 35294-3410.
E-mail: mhadley@uabmc.edu

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RECOMMENDATIONS

Level III

- Early closed reduction of cervical spinal fracture/dislocation injuries with craniocervical traction for the restoration of anatomic alignment of the cervical spine in awake patients is recommended.
- Closed reduction in patients with an additional rostral injury is not recommended.
- Magnetic resonance imaging is recommended for patients with cervical spinal fracture dislocation injuries if they cannot be examined during closed reduction because of altered mental status or before either anterior or posterior surgical procedures when closed reduction has failed. Prereduction magnetic resonance imaging performed in patients with cervical fracture dislocation injuries will demonstrate disrupted or herniated intervertebral disks in one-third to one-half of patients with facet subluxation injuries. These findings do not appear to influence outcome following closed reduction in awake patients, and therefore, the utility of pre-reduction MRI in this circumstance is uncertain.

RATIONALE

In the clinical scenario of traumatic cervical spine fractures and cervical facet dislocation injuries, narrowing of the spinal canal caused by displacement of fracture fragments or subluxation of 1 vertebra over another frequently

produces spinal cord injury. Reduction of the dislocation deformity helps to restore spinal alignment and the diameter of the bony canal by eliminating bony compression of the spinal cord resulting from the vertebral fracture and/or subluxation. By carrying out reduction early after injury, decompression of the spinal cord may lead to improved neurological outcome. Up until 2001, several investigators described positive results with large series of patients treated with initial closed reduction of cervical fractures and facet dislocation injuries with negligible rates of neurological complications. In 2002, the guidelines author group of the Joint Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons published a medical evidence-based guideline on this important topic.¹ Concurrently, descriptive series of patients with facet dislocation injuries were reported describing a high incidence of cervical disk herniation (in addition to the fracture/dislocation injury) identified on prerelation magnetic resonance imaging (MRI). In addition, several case reports and small series of patients who worsened neurologically following closed cervical spinal reduction were published. Several of these reports impugned ventral compression of the spinal cord by displaced disk material as causative. The purpose of this updated qualitative medical evidence-based review is to address the following issues:

1. Is closed reduction safe and effective for reducing cervical spinal deformity/spinal cord compression in patients with cervical fractures and/or facet dislocation injuries?
2. What is the risk of neurological injury following closed reduction of acute traumatic cervical fractures/facet dislocation injuries?

ABBREVIATION: MUA, manipulation under anesthesia

SEARCH CRITERIA

To add to and update the previously analyzed medical evidence on this issue, a new National Library of Medicine (PubMed) computerized literature search was performed. Medical subject headings queried included “facet dislocation” or “fracture” or “dislocation” and “cervical spine.” This search resulted in 6705 citations. This search was combined with the term “reduction,” yielding 527 potential citations. English language citations with abstracts limited to human subjects yielded 380 potential references. Restricting the search to 2001 to 2011 further refined the results to 155 citations. The abstracts of each of these citations were reviewed. As before, clinical series dealing with adult patients in the acute setting were selected. Case reports and case collections were included. Additional references were culled from the reference lists of the articles reviewed. Nine additional articles with clinical data germane to the issue of closed reduction of cervical spinal fractures were identified. These articles are summarized in the text, provided in Evidentiary Table format (Table), and included in the bibliography.

As observed in the previous medical evidence-based review, there were no randomized clinical trials, no prospective cohort studies, and no case-control studies. The publications identified consisted of case series of patients with acute or subacute unilateral or bilateral cervical facet dislocation injuries and provide Class III medical evidence. In contrast to the original spinal cord injury guidelines publication, no report of permanent neurological deterioration following or resulting from closed reduction of a cervical spinal fracture injury has been published since 2000.

SCIENTIFIC FOUNDATION

Closed reduction of cervical spinal deformity resulting from facet dislocation by manipulation was first described by Walton² in 1893. Crutchfield³ introduced tongs for inline traction-reduction in 1933, and similar techniques have been successfully used for traction-reduction of cervical deformity by a large number of authors.⁵⁻²² Observations by Evans and Kleyn popularized reduction under anesthesia, although other authors condemned the procedure as potentially dangerous compared to craniocervical traction-reduction. Manipulation under anesthesia (MUA) has been a common technique, usually used following failure of traction-reduction but occasionally used as a primary means of achieving reduction.^{6,15,21,22} Only 1 cohort study has been performed comparing the 2 modalities. Lee et al²³ found a higher rate of success and a lower complication rate with traction-reduction as opposed to MUA. The significance of their results is questionable because of the historical cohort design of the study. Lee et al attributed the higher complication rate in the MUA group to the effects of anesthesia on perfusion of the injured spinal cord. It is possible, however, that advances in the pharmacological and medical management of spinal cord-injured patients over the 10-year period of data accrual accounted for the improved results the authors noted in the traction-reduction

group. For this reason, the evidence provided by this study is considered to be Class III medical evidence.

THE EFFICACY OF CLOSED REDUCTION

In 2002, the guidelines author group of the Joint Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons/Congress of Neurological Surgeons published a medical evidence-based guideline on this issue.¹ That review reported the efficacy of closed reduction of acute cervical spinal fracture dislocation injuries derived from combined case series published in the literature to that point; > 1200 patients were treated with closed reduction, 80% (approximately) successfully. The reported neurological complication rate, permanent and transient combined, was low.

Four additional retrospective series and 3 case reports dealing specifically with closed reduction were identified in the current review that were not part of the original guideline publication, adding another 195 reported cases of closed reduction of cervical spinal fracture dislocation injuries for consideration. In 1991, Beyer et al²⁴ described their experience with a series of 34 patients who had acute traumatic unilateral facet dislocations or fracture dislocations of the cervical spine, 28 of whom were treated with attempted closed reduction. Ten of 28 injuries were successfully reduced with halo traction and achieved anatomic realignment. Eleven had improvement in alignment but incomplete anatomic reduction. Three patients had residual neurological deficits following traction reduction, although they did not deteriorate with traction. Seven patients had dislocation injuries that could not be reduced with traction. The authors described increased difficulty with the reduction of unilateral facet dislocation injuries.

O'Connor et al²⁵ in 2003 reported 21 patients with subaxial cervical facet injuries treated with attempted closed reduction. Eleven patients were reduced successfully. Closed reduction was not successful in any patients with a fracture dislocation injury \geq 5 days old ($n = 5$). One patient had a transient neurological deterioration. Traction up to 36 kg was employed. Koivikko and colleagues²⁶ successfully reduced cervical fracture dislocation injuries in 62 of 85 patients (73%) they treated with craniocervical traction. Their 2004 report cited 1 patient who experienced neurological deterioration following successful reduction. The temporal association of the deterioration with the closed reduction was not clear from the text of the report. Personal communication with the primary author revealed that the patient deteriorated while in traction for definitive treatment, not in association with closed reduction of the fracture dislocation injury.

In the same year, Anderson et al²⁷ reported their retrospective series of 45 patients who underwent reduction of unilateral and bilateral traumatic cervical spinal facet dislocation injuries. Eighty-nine percent of their patients underwent successful closed reduction. The authors found that motor score on presentation and patient age were statistically related to final motor score. Those with preserved neurological function at presentation and

younger patients tended to do better. Time to reduction did not correlate with improved motor score outcome in their study. However, their analysis suffers from the fact that nearly two-thirds of the original cohort were excluded from analysis because of incomplete medical records.

Reindl et al²⁸ in 2006 described their experience with anterior fusion/internal fixation for cervical spinal facet dislocation injuries. Thirty-three of the 41 patients they treated achieved successful closed reduction (80%). One patient had transient neurological deterioration due to closed reduction that resolved at 1 year following surgery. All 41 patients were treated anteriorly, including 8 with dislocation injuries that could not be reduced with traction. Only 2 patients treated anteriorly could not be reduced/stabilized with interbody fusion and internal fixation. Those 2 patients subsequently required posterior reduction, stabilization, and fusion.

Class III medical evidence supports the efficacy of closed reduction of acute traumatic cervical spinal fracture dislocation injuries. A number of investigators have suggested that early reduction of the traumatic cervical spinal deformity/restoration of the spinal canal improves neurological outcome.^{1,10,15,27,29-33} To date, that intuitive supposition has yet to be supported by Class I or Class II medical evidence.

THE RISK OF CLOSED REDUCTION OF CERVICAL SPINAL INJURIES

The incidence of neurological deterioration related to closed reduction remains low. Before 2001, the reported permanent neurological complication rate was < 1.0%.^{5,7,11,13-21,31,34-39} Of the 11 patients reported to develop new permanent neurological deficits with attempted closed reduction, 2 had root injuries, and 2 had ascending spinal cord deficits noted at the time of reduction.^{11,13,14,20} Seven patients were noted to have decreased American Spinal Injury Association motor scores after reduction; however, neither the nature nor the cause of the new deficits in these patients was described.¹⁵ The current literature review failed to uncover any other reports of patients who suffered a permanent neurological deficit related to closed reduction.

Transient neurological deterioration following closed reduction has also been reported with an incidence between 2% and 4%. Before 2001, temporary deficits were described in 20 patients of 1200 reported. These deficits reversed spontaneously or improved following reduction of weight or following open reduction.^{11,13-15,21,31} The causes of neurological deterioration associated with closed reduction in these and other series included overdistraction, failure to recognize a more rostral noncontiguous lesion, disk herniation, epidural hematoma, and spinal cord edema.^{11,13,16,20,31,40-42}

Mahale et al⁴³ reviewed 16 cases of neurological deterioration in patients with cervical spinal cord injuries following reduction of cervical facet dislocation injuries. Seven of the 16 patients developed complete cord injuries, 6 following open reduction and 1 following manipulation under anesthesia. Five patients developed partial injuries, 3 following MUA, 2 following closed

traction-reduction, and 1 following open reduction. Of the 2 patients who deteriorated following closed reduction, 1 patient was found to be overdistraction. Minor injuries were suffered by the remaining 3 patients, including 1 patient who deteriorated when the skull traction pins slipped, 1 patient who deteriorated in a plaster brace, and 1 patient who lost reduction and had neurological worsening. Nine of the 16 patients whom Mahale et al described were investigated with myelography following deterioration, 2 patients with MRI, and 1 patient with CT. A disk protrusion was noted in 1 patient, and a “disk prolapse with hematoma” was noted in another. Both of these patients were treated conservatively. The most common imaging finding in these 9 patients was cord edema.

Four additional retrospective series and 3 case reports dealing specifically with closed reduction for cervical spinal injuries were identified in the current review, adding another 195 reported cases of closed reduction reported since 2001. Four patients in this cohort were reported to suffer transient neurological deterioration in conjunction with closed reduction.^{25,28,44} The cause of the deterioration was not specified in three of the patients and was attributed to ossification of the posterior longitudinal ligament in the fourth. Three of the 4 patients experienced neurological recovery following surgical treatment.

PREREDUCTION MRI

Reports of neurological deterioration following closed or open posterior reduction of cervical fracture/dislocation injuries has led some authors to recommend the use of prereluction MRI to assess for ventral cord compromise caused by traumatic disk disruption. The risk of extruded disk material exacerbating neurological compression is the main concern related to closed reduction. However, prereluction MRI assessment requires the transport of a patient with a potentially unstable cervical spinal fracture/dislocation injury to the MRI suite. The use of prereluction MRI may delay reduction of the spinal deformity and therefore may delay decompression of the compromised spinal cord. If stabilization of the unstable cervical spine protects against additional injury to the cervical spinal cord, the information gained by prereluction MRI must be of sufficient value to warrant the delay in treatment and the associated potential morbidity of transport.

Several authors have reported the prevalence of MRI-documented disk herniation in association with cervical facet injury. Harrington et al¹⁵ reported a series of 37 patients managed with closed reduction. Postreduction imaging revealed a disk herniation in 9 patients, four of whom underwent later anterior decompression. Doran et al⁴⁵ reported a series of 13 patients drawn from 4 institutions over an unspecified time period. All patients underwent MRI evaluation, four of which were performed before reduction. Herniated disks were visualized in 10 patients; bulging disks were identified in 3 patients. No patient treated developed a permanent neurological deficit as a result of attempted closed reduction. Vaccaro et al⁸ studied 11 consecutive patients with prereluction and postreduction MRI. The authors found

a herniated disk in 2 patients in the prerelief group and in 5 of 9 patients who underwent successful closed reduction. Grant et al⁴⁶ obtained postreduction MRI studies on 80 patients treated with closed reduction and found herniated or bulging disks in 46%. Rizzolo et al³⁹ found evidence of disk disruption/herniation in 55% of patients studied with prerelief MRI. Awake and alert patients underwent closed reduction with no neurological deterioration. The authors did not attempt closed reduction in patients who were not awake. The clinical implications of the findings of a disk herniation on a prerelief MRI were questioned by the authors.

In 2006, Dauraut et al⁴⁷ studied the risk of closed reduction using a unique traction device to monitor reduction with MRI. Seventeen nonconsecutive patients were studied; 11 of 17 were successfully reduced with closed craniocervical traction, and 9 of those 11 patients achieved complete spinal cord decompression. One patient had incomplete decompression, and 1 patient had none. Interestingly, all soft disk herniations identified before the initiation of closed reduction were reduced back into the disk space as part of the traction-reduction process.

Despite the paucity of evidence regarding the value of prerelief MRI in the patient who has a cervical spinal dislocation, the topic remains controversial. Lee et al²³ in 2009 published a review on the topic and found no medical evidence-based guidelines for the treatment of the obtunded patient with a cervical dislocation. Arnold et al³⁵ performed a survey of 29 spinal surgeons from The Spine Trauma Study Group asking for their management responses to ten clinical scenarios related to acute unilateral and bilateral cervical facet dislocation injuries. There was substantial variability among surgeons regarding the need for prerelief MRI, depending on the clinical scenario (42%-77%), and little agreement regarding open or closed reduction to reduce the injury or the operative approach to provide definitive surgical treatment. In 2004, Koivikko et al²⁶ reported their experiences with a series of 85 patients treated for cervical fracture/dislocation injuries. Sixty-two experienced successful reduction with closed cervical traction; the others required operative reduction. No patients underwent prerelief MRI, and no patient deteriorated neurologically as a result of closed reduction. All surgical patients were treated with posterior interspinous wiring with fusion. Despite these results, the authors admit to more recent use of prerelief MRI in the management of patients with cervical fracture/dislocations since their publication.

Neurological deterioration from extruded disk material has been reported to occur in conjunction with both anterior and posterior open reduction following failed closed reduction. Eismont et al³⁴ reported a series of 63 patients managed with closed traction-reduction followed by open reduction if closed reduction was unsuccessful. One of these patients worsened following posterior open reduction and fusion. A herniated disk was found ventral to the cord on postprocedure myelography. Herniated disks were found in 3 other patients who failed closed reduction and in 2 patients with static neurological deficits

following fracture/dislocation reduction (1 open, 1 closed). One of these patients deteriorated after subsequent anterior cervical discectomy and fusion. Olerud and Jónsson³² described 2 patients found to have disk herniations on postreduction MRI or computed tomographic myelography. Both patients deteriorated after open reduction following failure of attempted closed reduction. Robertson and Ryan¹⁹ reported 3 patients who deteriorated during management of cervical subluxation injuries. One of their patients worsened during transport to the hospital. That patient's vertebral injury was found to have spontaneously partially reduced. MRI revealed a disk fragment compressing the cord. A second patient deteriorated following posterior open reduction. MRI revealed disk fragments compressing the ventral cord. Mahale et al⁴³ reviewed 16 cases of neurological deterioration in patients with cervical spinal cord injuries following reduction of facet dislocations. Seven of the 16 patients developed complete cord injuries, 6 following open reduction and 1 following manipulation under anesthesia. Preoperative MRI to assess for the presence of a significant disk herniation with the potential to cause spinal cord compression and neurological deficit when closed reduction has failed is recommended on the basis of these reports.

Review of the available literature reveals only 2 documented cases of neurological deterioration associated with attempted closed reduction of cervical spine fracture/dislocation injuries resulting from cord compression from disk herniation.^{13,48} Both of these cases were characterized by deterioration hours to days following closed reduction. A number of large clinical series have failed to establish a relationship between the presence of a prerelief herniated disk and subsequent neurological deterioration with attempted closed traction-reduction in awake patients.

SUMMARY

In the data derived from the literature published to date, closed reduction of fracture/dislocation injuries of the cervical spine by traction-reduction appears to be safe and effective for the reduction of acute traumatic spinal deformity in awake patients. Approximately 80% of patients will have their cervical fracture dislocation injuries reduced with this technique. The overall permanent neurological complication rate of closed reduction is approximately 1%. The associated risk of a transient injury with closed reduction appears to be 2% to 4%. Closed traction-reduction appears to be safer than MUA.

There are numerous causes of neurological deterioration in patients whom harbor unstable cervical spinal injuries. These include inadequate immobilization, unrecognized rostral injuries, overdistraction, loss of reduction, and cardiac, respiratory, and hemodynamic instability. Therefore, an appropriately trained specialist must supervise the treatment, including attempted closed reduction, of patients with cervical spine fracture dislocation injuries.

Although prerelief MRI will demonstrate disk herniation in up to half of patients with acute cervical spinal facet subluxation

TABLE. Evidentiary Table: Closed Reduction^a

Citation	Description of Study	Results	Evidence Class	Conclusions
Tumialán et al, ³³ <i>Spine</i> , 2009	Case report	Successful closed reduction of spondyloptosis of C7 on T1	III	Traction reduction of spondyloptosis is safe.
Cowan et al, ²⁹ <i>New England Journal of Medicine</i> , 2008	Case report	Improvement in neurological deficits with closed reduction	III	Rapid intervention can allow recovery from traumatic spinal cord injury.
Darsaut et al, ⁴⁷ <i>Spine</i> , 2006	17 patients, prospective nonconsecutive series, reduction under MRI	Reduction successful in 11 of 17 patients; 10 of 11 reductions achieved spinal cord decompression	III	Traction reduction achieves spinal canal decompression.
Reindl et al, ²⁸ <i>Spine</i> , 2006	41 patients, retrospective case series of patients treated with anterior fusion for cervical dislocations	33 of 41 cases reduced successfully; 1 patient deteriorated during surgery but recovered at 1 y	III	Closed reduction successful in most cases. Anterior surgery sufficient for stabilization.
Koivikko et al, ²⁶ <i>European Spine Journal</i> , 2004	85 patients, case series with historical control subjects	62 of 85 patients reduced successfully	III	No neurological deterioration during traction reduction.
Anderson et al, ²⁷ <i>Spine Journal</i> , 2004	45 patients (of 132), retrospective study to determine a statistical model to predict neurological outcomes	88% successfully reduced with closed reduction; no patient deteriorated neurologically	III	Age and initial motor score predict neurological outcome. Timing of reduction did not correlate to outcome.
O'Connor et al, ²⁵ <i>International Orthopaedics</i> , 2003	21 patients, retrospective case series	11 of 21 patients reduced successfully; 1 patient with transient neurological deficit	III	Anterior translation correlates to neurological deficit.
Grant et al, ⁴⁶ <i>Journal of Neurosurgery</i> , 1999	82 patients	Successful reduction in 97.6%	III	Closed reduction is effective and safe despite high incidence of MRI-demonstrable disk injuries/herniations.
	Retrospective series	Average time to reduction, 2.1 ± 0.24 h		
	All closed C-spine injuries with malalignment included	Overall ASIA scores improved by 24 h following reduction		
	Unilateral and bilateral locked facets	1 patient deteriorated 6 h after reduction (probable root lesion)		
	Early rapid closed reduction attempted in all patients	46% had disk injury on MRI, 22% had herniation		
	MRI scans obtained after reduction	Disk injury on MRI correlated with cord edema on MRI		
	ASIA and Frankel grades determined on admission and 6 and 24 h	Successful reduction in 97.6%		
	Weight up to 80% of patient's body weight			
Vital et al, ²² <i>Spine</i> , 1998	168 patients, retrospective series, unilateral and bilateral	43% reduced by traction without anesthesia (time < 2 h)	III	Authors promote their protocol as a safe and effective means for reduction and stabilization of fractures.
	Employed manipulation under general anesthesia in minority of cases	30% reduced by manipulation under anesthesia		
	Used relatively light weights (maximum, 8.8 lb plus 2.2 lb per level for maximum of 40 lb)	27% reduced intraoperatively		

(Continues)

TABLE. Continued

Citation	Description of Study	Results	Evidence Class	Conclusions
Lee et al, ³¹ <i>Journal of Bone and Joint Surgery</i> , 1994	All patients operated on immediately after reduction or after failure of reduction	5 patients did not reduce (delayed referral, surgical error)	III	Traction superior to MUA. Both procedures safe and effective.
	MRIs not done before reduction (although disks noted in 7 patients?)	Authors observed no cases of neurological deterioration		
	210 patients	Reduction successful:		
	Rapid traction-reduction in 119	MUA, 66/91 (73%)		
	Manipulation under anesthesia in 91	RT, 105/119 (88%)		
	Retrospective historical cohort study	All failures in RT group were due to associated fractures or delayed referral		
Cotler et al, ³⁹ <i>Spine</i> , 1994	Groups similar except traction group had longer delay to treatment	Time to reduction (RT), 21 min	III	Reduction with weights up to 140 lb is safe and effective in monitored setting with experienced physicians.
	Weights up to 150 lb used	MUA, not reported		
	No MRI done before reduction	No loss of Frankel grade in either group		
	24 patients (all awake)	6 MUA and 1 RT had deterioration on ASIA score		
	All acute injuries	All 24 reduced		
	Prospective study	No incidence of neurological deterioration		
Mahale et al, ⁴³ <i>Journal of Bone and Joint Surgery</i> , 1993	No fractured facets	Manipulation used in addition to weights in 9 patients (when facets perched)	III	Numbers of patients subjected to each treatment arm not given. Purely a descriptive article.
	All acute injuries	Time required ranged from 8 to 187 min		
	Weights up to 140 lb used			
	No CT or MRI done			
	341 patients treated for traumatic dislocations of cervical spine	Complete injuries: 6 after OR, 1 after manipulation		
	15 suffered neurological deterioration	Incomplete injuries: 1 after OR, 3 after manipulation, 2 after traction, 1 during application of cast		
Variety of treatments used to reduce deformity (4.3%)	Radiculopathy: 1 (occurred when tongs slipped during traction)	Deterioration delayed in 11 patients		Only conclusion is that neurological deterioration can occur.

(Continues)

TABLE. Continued

Citation	Description of Study	Results	Evidence Class	Conclusions
Hadley et al, ³⁸ <i>Neurosurgery</i> , 1992	68 patients	58% of patients had successful reduction	III	Early decompression by reduction led to improved outcomes based on fact that patients who did best were reduced early (< 5-8 h). No comparison possible between CR and ORIF because of small numbers.
	Retrospective series	Overall, most patients (78%) demonstrated neurological recovery by last follow-up (not quantified)		1.2% permanent deficit (root) related to traction.
	Facet fracture dislocations only	7 patients deteriorated during "treatment" (6 improved following ORIF, 1 permanent root deficit following traction)		
	Unilateral and bilateral locked facets	No MRI data reported		
	66 treated with early attempted closed reduction (2 late referrals)			
	Average weights used for successful reduction were between 9 and 10 lb per cranial level			
Beyer et al, ²⁴ <i>Journal of Bone and Joint Surgery</i> , 1991	34 patients	Reduction successful in 10 of 28 injuries; 3 patients with residual neurological problems	III	Open reduction more successful in maintaining reduction than halo vest treatment.
	Retrospective series			
	24 treated nonsurgically 10 treated with open reduction and posterior fusion			
Star et al, ⁵ <i>Spine</i> , 1990	57 patients	53 of 57 (93%) reduced	III	Closed reduction is safe and effective for decompressing cord and establishing spinal alignment.
	Retrospective series	Mean time to reduction was 8 h		
	Unilateral and bilateral injuries	No patient deteriorated a Frankel grade		
	Early rapid reduction attempted in all patients	2 patients lost root function, 1 transiently		
	No MRI done before reduction	45% improved 1 Frankel grade by time of discharge; 23% improved less substantially		
	1 patient was a delayed transfer	75% of patients required > 50 lb		
	Weights up to 160 lb (began at 10 lb)			
	Frankel grades recorded at admission and discharge			

(Continues)

TABLE. Continued

Citation	Description of Study	Results	Evidence Class	Conclusions
Sabiston et al, ²¹ <i>Journal of Trauma</i> , 1988	39 patients	35 of 39 (90%) patients successfully reduced	III	Closed reduction with up to 70% of body weight is safe and effective for reducing locked facets.
	Retrospective series, unilateral and bilateral injuries	Average weight used, 62.5 lb		Authors state that patients seen in delayed fashion (> 10 d) are unlikely to reduce (no evidence presented).
	Up to 70% of body weight used	No neurological deterioration		
	All acute injuries	Failures due to surgeon unwillingness to use more weight		
Maiman et al, ⁴⁸ <i>Neurosurgery</i> , 1986	No MRI 28 patients	10 of 18 reduced with traction	III	Mixed group of patients and treatments. In general, traction seemed to be safe.
	Variety of treatments offered	No patient treated by authors deteriorated		
	No MRI	1 referred patient had an overdistraction injury		
Kleyn, ⁴² <i>Paraplegia</i> , 1984	18 patients had attempt at closed reduction (maximum weight, 50 lb) 101 patients	82 of 101 successfully reduced (4 open reduction, 6 partial reduction accepted, 9 no further attempt owing to poor condition of patient)	III	Traction followed by MUA is safe, usually (80%) effective, and may result in improved neurological function.
	Unilateral and bilateral, all with neurological involvement	37 of 45 incomplete lesions improved		
	All treated with traction	7 of 56 complete lesions improved		
	If injury < 24 h, MUA attempted initially; if reduction fails with maximum of 18 kg weight, MUA performed Before MRI	No neurological deterioration		
Sonntag, ⁷ <i>J Neurosurg</i> , 1981	15 patients	Reduction with traction successful in 10 patients	III	Stepwise algorithm (traction, manual manipulation, operative reduction) is indicated. Closed reduction by weight application is the preferred method for reduction of deformity.
	Retrospective analysis	5 failed: 1 with C1 fracture that did not allow traction, 2 with fractured facets, 1 with radicular symptoms worsened by traction (transient), 1 with an ascending spinal cord injury (patient died of pulmonary complications 2 wk later)		
	All bilateral locked facets All acute injuries			

(Continues)

TABLE. Continued

Citation	Description of Study	Results	Evidence Class	Conclusions
Shrosbree, ⁶ <i>Paraplegia</i> , 1979-1980	Manual traction, tong traction, and open reduction used	70 of 95 unilaterals reduced (74%)	III	Discarded patients and lack of statistical analysis preclude firm statements. Highly suggestive paper. Conclusions: Traction followed by manipulation is safe and usually effective, and reduction seems to improve outcome (or patients who are reducible do better).
	216 patients identified with locked facets	77 of 121 bilaterals reduced (64%)		
	Used traction (no weight specified) followed by manipulation under anesthesia if traction failed	No neurological morbidity reported		
Burke and Berryman, ¹¹ <i>Journal of Bone and Joint Surgery</i> , 1971	Before MRI	86 died within 3 mo, excluded from series	III	MUA and traction both safe if proper diagnosis and careful attention paid to radiographs.
	41 patients treated by MUA, light traction followed by induction of anesthesia and intubation, followed by manipulation under anesthesia if necessary (same as Evans)	37 of 41 successfully reduced by MUA		
	32 patients treated with traction alone	21 of 25 reduced with traction before anesthetic		
	3 treated by traction after manipulation failed	7 patients were judged too sick for anesthesia and underwent traction for stabilization, not reduced		
	C7-T1 not attempted	2 cases of neurological deterioration: 1 overdistraction, 1 unrecognized injury		
Evans, ³⁰ <i>Journal of Bone and Joint Surgery</i> , 1961	Before MRI	17 patients treated by induction of anesthesia and intubation, sometimes with manipulation under anesthesia	III	Reduction under anesthesia safe and effective. Small series.
	Before MRI	All successfully reduced, 2 unchanged, 2 died, 13 improved		

^aASIA, American Spinal Injury Association; CT, computed tomography; MRI, magnetic resonance imaging; MUA, manipulation under anesthesia; OR, operating room.

injuries, the clinical importance of these findings is unknown. Only 2 case reports were found that document neurological deterioration caused by disk herniation following successful closed traction-reduction. In addition, several investigators have demonstrated the

lack of correlation between the MRI findings of disk herniation and neurological deterioration in this patient population. The use of prereluction MRI has therefore not been shown to improve the safety or efficacy of closed traction-reduction of patients with acute

cervical fracture dislocation injuries. MRI before fracture/dislocation reduction may unnecessarily delay spinal column realignment for decompression of the spinal cord. There is Class III medical evidence that supports early closed reduction of cervical fracture/dislocation injuries with respect to neurological recovery. Prereduction MRI in this setting is not necessary. The ideal timing of closed reduction of cervical spinal fracture dislocation injuries is unknown, but many investigators favor reduction as rapidly as possible after injury to maximize the potential for neurological recovery.^{10,15,29-32}

Patients who fail attempted closed reduction of cervical fracture injuries have a higher incidence of anatomic obstacles to reduction, including facet fractures and disk herniations. Patients who fail closed reduction should undergo more detailed radiographic study/MRI before attempts at open reduction. The presence of a significant disk herniation in this setting is a relative indication for an anterior decompression procedure, either in lieu of or preceding a posterior procedure.

Patients with cervical fracture dislocation injuries who cannot be examined because of head injury or intoxication cannot be assessed for neurological deterioration during attempted closed reduction. For this reason, an MRI before attempted reduction (open or closed) is recommended as a treatment option on the basis of Class III medical evidence.

KEY ISSUES FOR FUTURE INVESTIGATION

A prospective cohort study of patients with cervical spinal cord injuries resulting from facet fracture-subluxation injuries treated with or without prereduction MRI would provide Class II medical evidence in support of a treatment recommendation on this issue. This type of comparative study could also address issues of timing of closed reduction.

No prospective comparative study of closed reduction vs anterior decompression and stabilization for patients with MRI-documented herniated disks in association with unreduced cervical fracture/dislocation injuries has been performed. A prospective comparative study would provide Class II medical evidence in support of a treatment recommendation on this issue.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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