Unstable Cervical Spine Injuries: Specific Treatment Approaches

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Abstract

The goals in patients with unstable cervical spine injuries include (1) treatment of concomitant injuries, (2) preservation of neurologic function, (3) enhancement of neurologic recovery, (4) prevention of spinal deformity, and (5) maximization of functional recovery. The authors present an overview of protocols used for evaluation and treatment of unstable cervical spine injuries at their institution, representing knowledge accumulated in approximately 3,000 cases.

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Proper management of unstable spine injuries begins with the evaluation and treatment of patients by emergency medical personnel in the field. A high index of suspicion is the key to prevention of further neurologic injury during transport.

Emergency Evaluation

All patients with head or high-energy trauma, neurologic deficit, or complaints of neck pain must be assumed to have a cervical spine injury. The most common causes for missed spine injuries are multiple trauma, multiple noncontiguous vertebral fractures, and altered consciousness (e.g., coma, intoxication). As many as 16% of patients will have noncontiguous spine fractures, the most common cervical pattern being a fracture of the C1-2 complex and a second remote subaxial spine fracture.[1] Patients who present for evaluation with known or obvious cervical spine injuries also require a thorough screening for associated injuries. Nearly 50% of patients with acute spinal cord injury have other significant skeletal or visceral injuries.

Radiographic Evaluation

The initial radiographic assessment consists of a cross-table lateral film, which will reveal 70% to 79% of all cervical spine injuries. The addition of an anteroposterior (AP) and an open-mouth view increases the yield to 90% to 95%. The role of flexion-extension lateral x-ray films in an emergency setting remains controversial; we use these dynamic films in alert and cooperative patients without neurologic deficit who complain of neck pain. Unfortunately, a negative study does not rule out an acute injury because patients with acute cervical spine injury may have muscle spasm that masks cervical instability for up to 2 to 3 weeks. Therefore, despite a negative study, in any patient in whom the index of suspicion is high enough to obtain flexion-extension films, we recommend immobilization in a rigid cervical orthosis and follow-up films in 2 to 3 weeks.

Computed tomographic (CT) scans are reserved to delineate the bony anatomy of fractures seen or suspected on plain radiographs in those cases in which the lower cervical spine cannot be adequately visualized.

Plain tomograms may be useful to delineate minimally displaced horizontal fractures of the odontoid process or facets, which may be missed on axial CT images. Tomograms are also useful for preoperative and postoperative evaluation of the cervicothoracic junction.

Magnetic resonance (MR) imaging is indicated in (1) patients with complete or incomplete neurologic deficits, to search for and quantify the degree of spinal cord compression; (2) patients in whom the neurologic status deteriorates; and (3) cases in which there is a suspicion of posterior ligamentous injury despite negative plain radiographs. Recent studies have demonstrated that the incidence of disk injury complicating cervical spine trauma is significantly higher than initially thought and is greater than 50% in some injury patterns. Magnetic resonance imaging is contraindicated in patients with pacemakers, aneurysm clips, metallic fragments in the eye or spinal cord, or severe claustrophobia. Ventilatory support and cardiac monitoring of patients during MR imaging must be accomplished with nonferromagnetic equipment.

Neurologic Evaluation

Detailed and precise neurologic examination is critical to assessing both the initial status of the patient

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and the response to intervention. In our institution, motor and sensory evaluation is conducted with use of the guidelines established by the American Spinal Cord Injury Association.[2]

Initial Treatment

Immobilization

Immobilization is indicated for all patients with unstable cervical spine injuries. Any patient with a transient or continuing neurologic deficit must be considered to have an unstable spine until proved otherwise. Our general definition of instability for patients without neurologic deficits is a mechanical failure of any element of the spine resulting in shortening, lengthening, translation, rotation, or fracture. For these patients, a rigid cervical orthosis in many cases provides inadequate control; many patients require cervical skeletal traction.

Our preferred method of cervical traction is via Gardner-Wells tongs placed at a level 1 cm posterior to the external auditory canal and just above the pinna. Tongs should be made of MR imaging-compatible materials (e.g., titanium or graphite) so as not to interfere with subsequent imaging studies. Depending on the injury pattern, tongs placed slightly anterior impart an extension moment to the spine, and those placed slightly posterior impart a flexion moment. In the emergency room patients are placed on a manual turning frame (Stryker). On admission to the unit they are transferred to an automatic rotating bed. The weight required for immobilization of cervical spine injuries must be tailored to the individual injury, but in most cases 10 to 15 lb of weight is sufficient. The posttraction alignment of the spine should always be checked after application of initial and subsequent weights. In those cases in which the timing or logistics of a trauma resuscitation precluded thorough evaluation or application of traction, the patient should be maintained in a rigid cervical orthosis.

Closed Reduction

An attempted closed reduction is indicated in all cases of cervical spine injury demonstrating shortening, angulation, or translation. The goal of closed reduction is restoration of normal spinal alignment, which results in decompression of the spinal canal, enhancement of neurologic recovery, restoration of the stability of intact bone elements, and prevention of further neurologic injury. Animal and clinical studies demonstrate that the extent of neurologic recovery is influenced by the duration and the degree of neurologic compression. It is therefore our policy to attempt closed reduction as rapidly as possible on admission to our unit.

Closed reduction must always be attempted in a closely supervised setting with vigilant radiographic and neurologic monitoring. It is our strong belief that patients should be awake, alert, and cooperative to provide feedback during the procedure. Reduction is accomplished by means of a combination of skeletal traction, patient positioning, and postural bumps. The role of manipulation during closed reduction is controversial; the technique should therefore be reserved for those familiar with its indications and techniques.[3] The weight required for reduction of individual cervical spine injuries is quite variable, and the maximum amount of weight that can be safely applied is not known.[4]

Attempted closed reduction should be discontinued when (1) the spine is reduced, (2) more than 1 cm of distraction occurs at the zone of injury or another location, (3) the patient's neurologic status deteriorates, or (4) the physician believes that additional attempts have little or no chance of success. Following successful closed reduction, preoperative alignment of the spine can usually be maintained with 10 to 15 lb of axial traction. The patient must remain in a supine position. In selected patients with injuries that preclude halo application (e.g., those with skull fracture, chest tubes, or facial burns), we have found that preoperative immobilization of unstable fractures in a halo vest is safe and effective.[5]

Prevention of Perioperative Complications

Gastrointestinal bleeding, usually the result of peptic ulcer disease, has been reported to occur in up to 40% of patients and is most common 10 to 14 days following injury.[6-9] The risk of ulceration may be aggravated by the use of corticosteroids and can be combated through the use of H2 blockers and early enteral feeding. The incidence of deep venous thrombosis in spinal cord injury patients has been reported to be as high as 95% and is clinically relevant in 25% to 35% of patients. Our current prophylactic protocol calls for adjusted low-dose heparin and compression boots. Skin breakdown is best treated through prevention by means of vigilant nursing care and the use of rotating beds. Established ulcers must be aggressively treated with debridement, local wound care, and pressure relief.

General Principles of Surgical Treatment

Surgical decompression must be considered in all cases of radiographically demonstrable neurologic compression after realignment of the spine. Decompression is mandatory in the face of incomplete neurologic injury in order to promote recovery. In cases of complete neurologic injury, decompression may facilitate root recovery, which, in the cervical spine, may significantly improve functional status. If the neurologic examination is normal, decompression is not mandatory. If the injury resulting in neural compression also predisposes the spine to late deformity, however, decompression may be indicated as part of a procedure designed to restore structural integrity.

The surgical approach should be dictated by the anatomic location of neurologic compression, which in the overwhelming majority of patients occurs anteriorly as the result of vertebral body retropulsion or herniation of disk material. Accordingly, the vast majority of cervical decompressions are performed anteriorly. Laminectomy has little value and predisposes the patient to late kyphotic deformity and poor results except in those few patients with depressed laminar fractures causing posterior compression of the cord and in the rare patient with ankylosing spondylitis and epidural hematoma.

In most cases surgery—anterior, posterior, or both—is best performed on a turning frame. The Stryker frame incorporates a pulley to facilitate cervical traction. When the patient has been immobilized preoperatively in a halo-vest orthosis, traction can be applied through a halo bail. Alternatively, either the anterior or the posterior bars of the halo can be taped to the frame and the opposite vest and bars can be removed, allowing unrestricted access to the neck.

The indications for the use of spinal cord monitoring during surgery for the treatment of acute cervical spine injuries are not well delineated. We currently use somatosensory evoked potential monitoring for those patients with intact neurologic function below the level of injury in whom significant intraoperative manipulation of the spinal column is anticipated. Evidence of significant signal deformity is checked with a wake-up test.

Almost universally, patients at our institution who undergo surgical stabilization for acute cervical spine trauma are immobilized postoperatively in a halo vest. While we recognize that in some cases this may represent a certain degree of overtreatment, we have found that the halo vest is well tolerated by most patients and carries a low complication rate.[10] Once early signs of osseous healing are visible, patients are usually switched to a rigid cervical orthosis until healing is complete.

Treatment of Specific Injury Patterns

Upper Cervical Spine

In the upper cervical spine (occiput to C-2) there is a proportionally greater space available for the cord than in the lower cervical spine. Therefore, patients with fractures of C-1 and C-2 often present without neurologic deficit. Furthermore, if significant cord damage is caused by a high cervical fracture, patients are frequently dead on arrival and evaluation is not undertaken. In the upper cervical spine the most common patterns of injury seen in the emergency room are occiput–C-1 disruption, C-1 ring fracture, C1-2 disruption, C-2 ring fracture, and odontoid process fracture.

Occiput–C-1 Disruption

Occiput–C-1 disruption is a rare high-energy rotational injury that generally results in cord transection and death. Patients who survive present with either anterior or posterior dislocation of one or both occipital condyles on the lateral masses of C-1. This injury represents a failure of the ligamentous attachments of the occiput and C-1 and is extremely unstable. It is frequently associated with a fracture of C-1 or with C1-2 rotatory subluxation. Traction must be applied with extreme caution due to the risk of cord distraction. Treatment is open reduction and posterior occiput–C-1 fusion.

Ring Fracture of C-1

Pure axial loads transmitted to the lateral masses of C-1 via the occipital condyles result in a four-part burst, or Jefferson, fracture of C-1. Additional flexion moments may result in isolated anterior arch fractures, whereas extension moments may result in isolated posterior arch fractures. Most C-1 ring fractures are visible on lateral or AP radiographs. Accurate diagnosis requires axial CT scanning, which provides excellent cortical detail as well as evidence of healing. Ruptures of the transverse ligament and odontoid fractures are common associated injuries.

Most patients with C-1 ring fractures have no neurologic deficit, due to the capacious nature of the canal at C-1, as well as the decompressing effect of ring fractures. Treatment for 8 to 12 weeks in a rigid cervical orthosis can be contemplated for isolated anterior or posterior arch fractures, but Jefferson fractures and those associated with odontoid fractures are best treated with a halo. While not all fractures heal with osseous union, fibrous union is usually stable. Posterior cervical fusion may be required for those patients with transverse ligament tears and those who demonstrate late C1-2 instability.

C1-2 Injuries

Severe hyperflexion forces can result in rupture of the transverse ligament and anterior subluxation of the atlas on the axis. Diagnosed on the basis of an atlanto-odontoid interval of more than 4 mm, C1-2 instability is most often associated with long-track neurologic findings if the space available for the cord is less than 10 mm. The space available for the cord is defined as the distance between the posterior aspect of the dens and the anterior aspect of the posterior ring of C-1. Treatment is with immobilization in extension followed by early C1-2 posterior fusion. Frank dislocation of C-1 and C-2 is rare, most commonly anterior in direction, extremely unstable, and often fatal. Emergency room treatment is reduction followed by posterior atlantoaxial fusion.[11]

Extensive rotatory forces may result in unilateral or rotatory subluxation or dislocation of one inferior facet of C-1 on C-2. The most common radiographic finding is an asymmetry of the distance between the lateral masses and the odontoid seen on the open-mouth view. Diagnosis is confirmed with CT scanning. Treatment is with reduction in longitudinal traction followed by halo-vest immobilization. C1-2 fusion is reserved for patients with recurrent or irreducible dislocations.

Traumatic Spondylolisthesis of the Axis

Bilateral fracture of the pars interarticularis of the axis (hangman's fracture [Fig. 1]) occurs most frequently during motor vehicle accidents and is most commonly a result of extension and compressive loading forces generated when the cranium strikes the windshield. Most often the fracture of the pars interarticularis is minimally displaced or nondisplaced, and neurologic damage is unusual. However, the axial loading that contributes to the C-2 pars fracture is capable of causing additional subaxial vertebral burst fractures as well. Treatment of the C-2 fracture is 8 weeks of immobilization in a halo vest followed by 4 weeks in a rigid cervical orthosis.

Fig. 1 Hangman's fracture.

Bony union of the pars defect and occasionally spontaneous anterior C2-3 bony fusion are usual and should be documented with flexion-extension films.

In some cases, the fracture of the pars of C-2 is accompanied by forward angulation and / or translation of the superior portion of C-2 on C-3. The displacement is most likely the result of a secondary flexion moment applied after creation of the pars fracture and represents rupture of the posterior longitudinal ligament and damage to the intervertebral disk. This pattern is significantly more unstable, and initial treatment is reduction with gentle traction applied with the neck in some extension. Early halo-vest immobilization in extension may maintain adequate alignment, but significant loss of reduction mandates a return to traction until callus is visible. Healing with residual displacement has no effect on the clinical outcome.

Odontoid Fractures

Odontoid fractures account for up to 15% of all cervical spine fractures and are most frequent in older patients who sustain motor vehicle accidents or a blow to the head. The Anderson-D'Alonzo classification includes three types.[12] A type I fracture is an avulsion of the superior third of the odontoid above the transverse ligament. In a type II fracture, the fracture is through the narrow waist of the odontoid above the junction with the body of C-2. In a type III fracture, the fracture line extends into the body of C-2. Hyperflexion most likely causes an odontoid fracture with subsequent anterior displacement. Hyperextension generates odontoid fractures with posterior displacement. Associated fractures of the ring of C-1 are quite common; neurologic deficit is present in 15% to 25% of cases.

Diagnosis of odontoid fracture is frequently missed on plain films, particularly if the fracture is nondisplaced. Often the fractures are not visualized on CT either, due to the transverse nature of the fracture line. Therefore, AP and lateral tomography is the study of choice for the diagnosis and characterization of odontoid fractures.

In general, type I fractures are of no clinical consequence and are treated with a Philadelphia collar until comfort and stability are documented. Type III fractures have a high union rate and are best treated with halo-vest immobilization after reduction in traction. Type II fractures have the lowest rate of union following halo immobilization owing to the small area of bony contact and the watershed blood supply of the waist of the odontoid. Additional risk factors for nonunion include a greater degree of initial displacement, advanced age, and smoking.[13] Nondisplaced type II fractures should be treated with primary halo-vest immobilization, but displaced fractures require preliminary reduction in traction. Although the trial of halo-vest immobilization is usually attempted, the patient and physician should be aware of the significant risk of nonunion and the subsequent need for late C1-2 fusion. In older patients with significantly displaced fractures, primary C1-2 fusion after reduction in traction should be considered.

In patients with both an odontoid fracture and a fracture of the ring of C-1, occiput–C-2 fusion should be avoided. Immobilization in a halo vest usually promotes healing of the C-1 fracture, and fusion at a later date can be limited to C-1 and C-2 should nonunion of the odontoid occur. Some experts are now advocating primary anterior screw fixation for this complex, but we have no experience with this technique.

Subaxial Fractures

Accurate classification of subaxial cervical spine injuries speeds the delivery of appropriate diagnostic and therapeutic intervention. The mechanistic classification proposed by Ferguson and Allen provides useful information for planning the medical or surgical approach to unstable injuries.[14] Thorough knowledge of this classification scheme often enables prediction of injury to elements of the spine that appear normal on plain radiographs. In addition, knowledge of the mode of failure of spinal elements is useful in assessing the potential for late deformity and in planning the approach and technique of operative reconstruction.

The injury patterns recognized by the Ferguson-Allen classification are based on the position of the neck at the time of injury and the dominant mode of force application. Furthermore, each injury pattern is graded in terms of the degree of injury (bony or ligamentous) to the involved motion segment. A higher stage of injury is associated with a greater amount of displacement and a greater risk of neurologic injury. Injury designation is based on the mechanism of injury and review of plain radiographs.

Crucial to the differentiation of injury patterns is recognition that compressive loads result in shortening of vertebral elements, while distraction results in lengthening. In the Ferguson-Allen classification, the posterior longitudinal ligament and the structures anterior to it are considered the anterior column of the spine, and the structures posterior to the posterior longitudinal ligament are considered the posterior column of the spine. Although this classification is very useful, it cannot be universally applied; patients often present with injuries that represent a combination of injury patterns.

Compressive Flexion Injuries

The mechanisms that most commonly result in compressive flexion injuries (Fig. 2) are motor vehicle accidents and shallow dives. The most common levels of injury are C4-5 and C5-6. Compressive loads applied to the flexed spine result in compression of the anterior column of the spine and distraction of the posterior column. The resultant shortening of the anterior column and lengthening of the posterior column can be graded into five stages. In stages 1 and 2 (vertebral body blunting and beaking), the structural integrity of the anterior column is partially intact, and complete ligamentous failure of the posterior annulus has not occurred. While there is a risk of late kyphotic deformity, most patients can be managed in a rigid cervical orthosis or halo-vest orthosis for 8 to 12 weeks. In stage 3 injuries (fracture of the vertebral body without displacement), complete posterior ligamentous disruption is possible and should be evaluated with MR imaging. A halo-vest orthosis is sufficient for patients with an intact posterior column. In patients with ligamentous disruption, however, the risk of late kyphotic deformity is high; they should be treated with posterior cervical fusion and postoperative halo immobilization.

Patients with stage 4 and 5 lesions (posterior displacement of the vertebral body) often present with profound neurologic deficit. There is complete failure of the anterior column of the spine, and placement of tongs in extension and the use of extension rolls often results in only partial realignment of the spine. For the purposes of decompression and reconstruction, patients with these high-energy injuries require anterior decompression (corpectomy) and anterior strut-graft reconstruction. Due to high rates of graft complications and the propensity for late kyphotic deformity, anterior reconstruction is supplemented with posterior fusion and postoperative halo immobilization. The role of anterior cervical internal fixation (i.e., plates) remains controversial. Stage 4 lesions without neurologic deficit must be examined with MR imaging to determine the status of the posterior ligamentous complex. Posterior fusion alone is an option if there is no significant cord compression. Current knowledge suggests that these patients are candidates for assessment of the degree of disk disruption and possibly even diskectomy.

Vertical Compression Injuries

Vertical compression injuries (Fig. 3) are most common following motor vehicle accidents, diving accidents, and direct blows to the top of the skull. The most common level of injury is at C6-7. The result of compressive forces applied to the

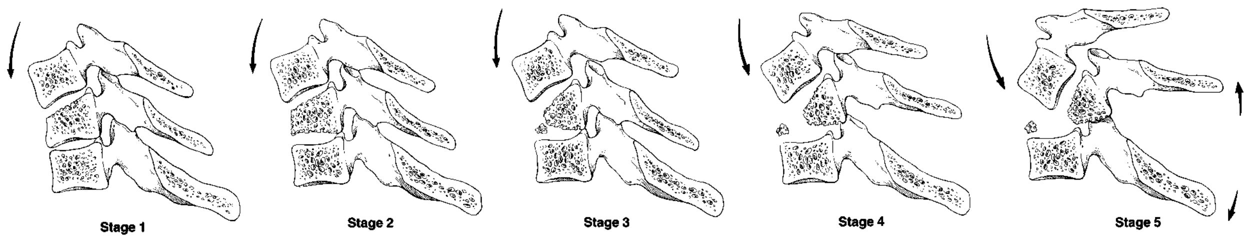

Fig. 2 Compressive flexion injury. **Stage 1:** Blunting and rounding off of anterosuperior vertebral margin. **Stage 2:** Loss of anterior height and beaklike appearance anteroinferiorly. **Stage 3:** Fracture line from anterior surface of vertebral body extending obliquely through subchondral plate and fracture of the beak. **Stage 4:** Some displacement (<3 mm) of posteroinferior vertebral margin into neural canal. **Stage 5:** Displacement (>3 mm) of posterior part of body. Although vertebral arch is intact, entire posterior ligamentous complex is ruptured.

spine in neutral alignment is shortening of the anterior and posterior column of the spine, which occurs in three stages. Stage 1 and 2 injuries involve cupping of one or both endplates of the vertebral body and represent partial failure of the anterior column. Neurologic injury is rare, and because the posterior ligamentous structures are uninjured, late kyphotic deformities are unusual. Most patients can be treated for 6 to 8 weeks in a rigid cervical orthosis or halo vest. Stage 3 injuries are defined as fragmentation and displacement of the vertebral body and are sometimes referred to as "burst fractures." Axial traction occasionally results in reduction of the fracture, but not consistently. Neurologic injury is common, and the presence of associated posterior element fractures is variable.

Patients with a neurologic deficit require anterior corpectomy and reconstruction to decompress the cord and roots to foster neurologic recovery. The need for adjunctive posterior fusion is based on the integrity of the posterior column of the spine. Treatment is most often the same for patients without neurologic deficit in order to prevent late kyphotic deformity. The degree of disk disruption is ill defined as yet and probably justifies MR imaging for soft-tissue assessment (disk, ligaments, cord) after attempted closed reduction or prior to operative care.

Distractive Flexion Injuries

Distractive flexion injury (Fig. 4) is the most common injury pattern and is most often caused by motor vehicle accidents and falls from a height. Injury is most common at C5-6 and C6-7. Distractive loads applied to the spine in a flexed position cause tensile failure (ligamentous or bony) and lengthening of the posterior column and may be associated with some compression and shortening of the anterior column. Shear forces generated by this injury pattern result in variable degrees of anterior translation of the superior vertebra of the involved motion segment. The amount of anterior displacement is dependent on the degree of posterior element failure. In general, less than 25% subluxation is indicative of a facet subluxation (stage 1); 25% to 50% subluxation, a unilateral facet dislocation (stage 2); and more than 50% subluxation, a bilateral facet dislocation (stage 3). Full body displacement is defined as a stage 4 injury. All stages of distractive flexion injury may be associated with facet fractures as well.

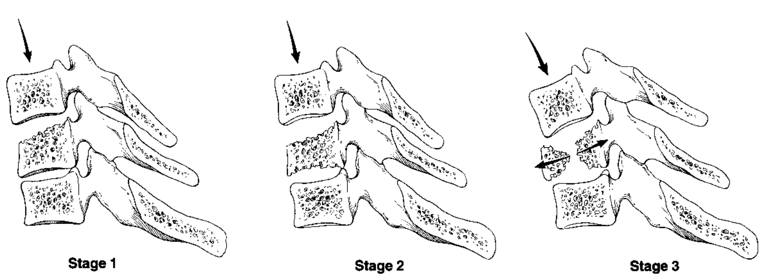

Fig. 3 Vertical compression injury. **Stage 1:** Central cupping fracture of superior or inferior endplate. **Stage 2:** Similar to stage 1, but fracture of both endplates; any fracture of the centrum is minimal. **Stage 3:** Fragmentation and displacement of vertebral body.

Closed reduction should be attempted for all stages of distractive flexion injury as soon as the patient is medically stable. Recent evidence from our spinal cord injury unit indicates that in patients with neurologic deficits, recovery is greater in those who underwent successful reduction less than 8 hours after injury. Several authors have offered formulas for determining the weight required for reduction of cervical spine dislocations, but none of these formulas has been proved effective. Some

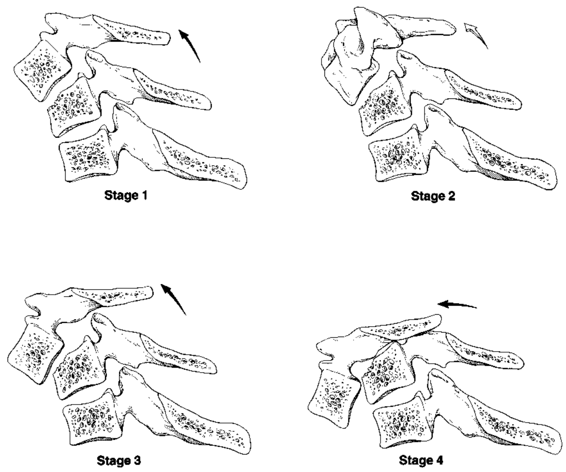

Fig. 4 Distractive flexion injury. **Stage 1:** Facet subluxation in flexion and divergence of spinous processes (flexion sprain); some blunting of anterosuperior vertebral margin as in a stage 1 compression flexion injury. **Stage 2:** Unilateral facet dislocation; there may be some rotary spondylolisthesis. **Stage 3:** Bilateral facet dislocation with about 50% anterior vertebral body displacement. Facets may have completely leapfrogged over those below or may be "perched." **Stage 4:** Full-width vertebral body displacement or completely unstable motion segment.

authors recommend using no more than 50 lb of weight for fear of overdistraction. Using a method described by one of the authors (J.M.C.), we routinely may include higher weights and have reported significantly higher success rates with closed reduction.[3,15,16] In a recent report of 81 consecutive attempted closed reductions using weights of up to 120 lb (average, 65 lb), the anatomic success rate was 91%.[16]

Following successful closed reduction, patients with distractive flexion injuries treated nonoperatively in the halo-vest orthosis have up to a 64% incidence of late instability.[17,18] We therefore prefer primary posterior cervical fusion using a triple-wire technique for all stages of distractive flexion injury. Unsuccessful closed reduction requires open reduction and posterior cervical fusion.

It has been recognized that 54% to 80% of patients with distractive flexion injuries have an associated acute disk herniation at the level of injury.[19-22] Catastrophic neurologic damage has been reported following closed reduction of this injury complex.[23] In all patients with this neurologic catastrophe, the closed reduction was done under general anesthesia. No case of neurologic deterioration caused by herniated nucleus pulposus during awake closed reduction has been reported. In 50 consecutive cases of unilateral or bilateral facet dislocation, we found a 54% incidence of herniated nucleus pulposus as diagnosed with MR imaging. All patients in this study underwent emergency attempted closed reduction while awake, with an anatomic success rate of 80%. In 24 patients a herniated disk had no effect on the anatomic and neurologic outcome. Neurologically, four patients improved and none worsened during attempted awake closed reduction. Based on the results of this study, we continue to recommend attempted awake closed reduction of all cervical spine dislocations.

We do not believe that MR imaging is indicated prior to routine reduction; the delay associated with obtaining an MR imaging study may compromise neurologic recovery. In patients in whom closed reduction fails, MR imaging is a prerequisite to open reduction. Patients with herniated disks should undergo anterior cervical diskectomy prior to reduction and fusion.

Compressive Extension Injuries

The mechanisms most commonly responsible for compressive extension injuries (Fig. 5) are motor vehicle accidents, falls, and diving accidents. Compressive extension injuries occur at all levels of the subaxial spine and may be associated with C1-2 injuries as well. The compression forces applied to the spine in extension result in early failure of the posterior column of the spine and later tensile failure of the anterior column. The early stages (stages 1 and 2) of compression extension injuries result in single- or multiple-level posterior element fractures without vertebral body displacement and are best managed with a rigid cervical orthosis. Later stages associated with vertebral body displacement are very unstable and require anterior fusion. Use of an anterior cervical plate as a tension band has been useful. Internal fixation and posterior fusion are often difficult due to fractures at multiple contiguous levels, but may be accomplished with plate-screw constructs.

Distractive Extension Injuries

Distractive extension injuries (Fig. 6) are most frequently caused by motor vehicle accidents and falls. The distractive forces applied to the spine in extension cause tensile failure and lengthening of both the anterior and posterior columns of the spine. Failure can be either bony or ligamentous; MR imaging is often helpful in determining the extent of soft-tissue injury. Injuries without evidence of vertebral body displacement on static and flexion-extension films (stage 1) can be treated with a rigid orthosis. Vertebral body displacement (stage 2) mandates fusion. Anterior fusion with plate fixation is most often successful. Posterior fusion with plates can be added in extremely unstable cases.

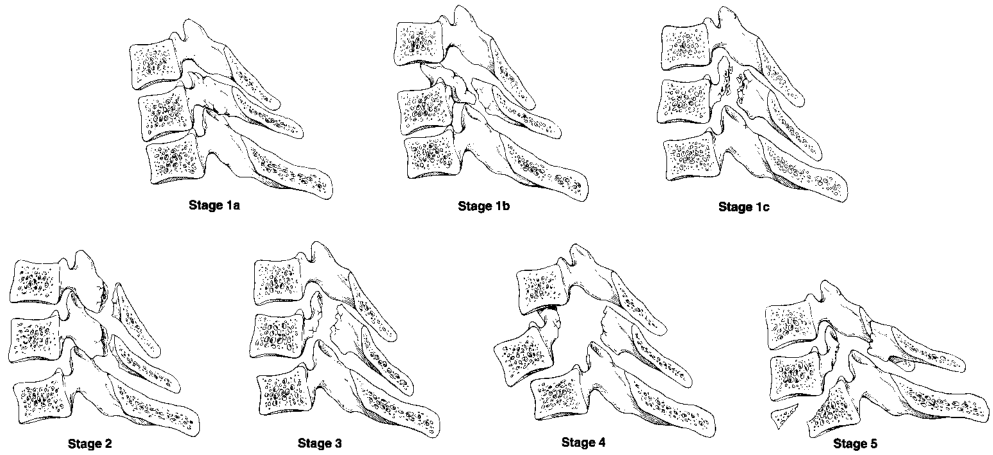

Fig. 5 Compressive extension injury. **Stage 1:** Unilateral vertebral arch fracture; may be through articular process (stage 1a), pedicle (stage 1b), or lamina (stage 1c); there may be rotary spondylolisthesis of centrum. **Stage 2:** Bilaminar fracture, which may be at multiple contiguous levels. **Stage 3:** Hypothetical modes not seen clinically by authors of classification, characterized by bilateral fractures of vertebral arch (articular processes, pedicles, or laminae) and partial-width anterior vertebral body displacement. **Stage 4:** Partial-width anterior vertebral body displacement. **Stage 5:** Full-width anterior vertebral body displacement.

Lateral Flexion Injuries

Lateral flexion injuries (Fig. 7) are most frequently caused by motor vehicle accidents and blows to the side of the head. The asymmetric nature of force loading in the coronal plane results in tensile failure of one side of the spine and compressive failure of the opposite side. Injuries without displacement (stage 1) can often be managed nonoperatively. Displaced injuries (stage 2) most often require surgical stabilization and fusion. The role of preoperative MR imaging is not well defined for this patient population.

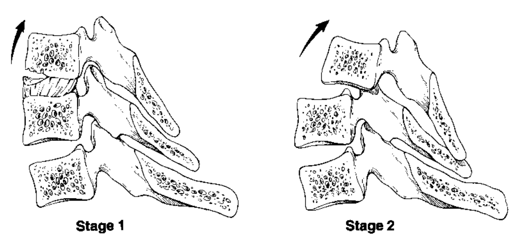

Fig. 6 Distractive extension injury. **Stage 1:** Failure of anterior ligamentous complex. Injury may be a nondeforming transverse fracture through the centrum or widening of disk space. **Stage 2:** Injury may be anterior marginal avulsion fracture of centrum. Some posterior ligamentous complex failure may be revealed by posterior displacement of upper vertebra. Fracture reduces in flexion.

Current Issues

Corticosteroids

The theoretical benefit of corticosteroids in patients with acute spinal cord injury is to decrease inflammation and minimize neural tissue damage and dysfunction at the cellular level. The theoretical disadvantages are immunosuppression and gastrointestinal bleeding. Initial studies using relatively low doses of steroids administered over the course of several weeks resulted in significant increases in the incidence of infection and gastrointestinal bleeding with little or no improvement in neurologic function.[24-26]

In a recent multicenter randomized study, Bracken et al[26] evaluated the safety and efficacy of methylprednisolone in doses larger than previously utilized; drug administration was started within 8 hours of admission and continued over the first 24 hours. The authors reported a significant improvement in motor scores in patients with motor-incomplete lesions who were treated with methylprednisolone as opposed to placebo and naloxone. The incidence of infection was 7.9% in treated patients, compared with 3.6% in the control subjects, and the incidence of gastrointestinal bleeding was 4.5%, compared with 3% in the controls. The shortcomings of the study include a lack of control over subsequent operative intervention between the study groups and the failure to mention the degree of functional motor improvement associated with increased motor scores. It must be reiterated that the study included only patients treated within 8 hours of blunt spinal cord injury and did not include penetrating spinal cord injuries.

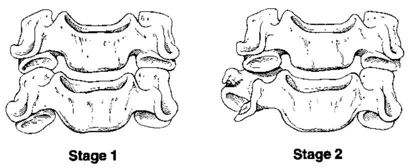

Fig. 7 Lateral flexion injury. **Stage 1:** Asymmetric compression fracture of centrum with associated vertebral arch fracture ipsilaterally; AP film shows no displacement. **Stage 2:** Displacement of ipsilateral arch fracture seen on AP view. There may also be ligamentous tension failure on contralateral side with facet separation.

The ultimate role of steroids in the acute treatment of spinal cord injury remains unclear. We currently administer the recommended bolus of 30 mg of methylprednisolone per kilogram of body weight, followed by an infusion of 5.4 mg / kg per hour for 23 hours to all patients with acute (of less than 8 hours' duration) blunt spinal cord injury.

Timing of Surgery

Initial studies of early surgical intervention (within less than 3 to 5 days) in patients with acute spinal cord injury reported increased mortality and neurologic deterioration, leading many authors to recommend a delay in operative intervention for 1 to 2 weeks. However, the degree of neurologic damage following experimental spinal cord injury in animals is affected not only by the degree but also by the duration of cord compression, leading other authors to recommend urgent decompression.

There can be no doubt that the practice of early decompression and stabilization of unstable spine injuries offers the benefits of patient mobilization, much as it does in all trauma patients. Furthermore, recent studies utilizing spinal cord monitoring and new anesthesia and operative techniques have led to no increase in morbidity and mortality following early surgical intervention.[27] It is therefore our bias to proceed with operative decompression and stabilization of patients with acute spinal cord injury in a medically expedient manner.

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