Treatment of Subaxial Cervical Spinal Injuries

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RECOMMENDATIONS

Level III:

- Closed or open reduction of subaxial cervical fractures or dislocations is recommended. Decompression of the spinal cord/restoration of the spinal canal is the goal.
- Stable immobilization by either internal fixation or external immobilization to allow for early patient mobilization and rehabilitation is recommended. If surgical treatment is considered, either anterior or posterior fixation and fusion is acceptable in patients not requiring a particular surgical approach for decompression of the spinal cord.
- Treatment of subaxial cervical fractures and dislocations with prolonged bed rest in traction is recommended if more contemporary treatment options are not available.
- The routine use of computed tomography and magnetic resonance imaging of trauma victims with ankylosing spondylitis is recommended, even after minor trauma.
- For patients with ankylosing spondylitis who require surgical stabilization, posterior long-segment instrumentation and fusion or a combined dorsal and anterior procedure is recommended. Anterior standalone instrumentation and fusion procedures are associated with a failure rate of up to 50% in these patients.

RATIONALE

Acute subaxial cervical spine injuries following trauma remain a common problem. These injuries are often associated with neurological deficits on presentation. Refinements in spinal instrumentation have led to an increased reliance on the operative treatment of subaxial cervical injuries. 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 have previously produced a medical evidence-based guideline on this topic and described nonsurgical and surgical treatment strategies for acute subaxial cervical spinal injuries.[1] Since the publication of that guideline in 2002, subsequent clinical data reported in the spinal literature have focused primarily on the use of internal fixation in the treatment of subaxial cervical fractures and dislocations. Case series describing both anterior- and posterior-based surgical techniques for patients with these injuries have been published. The purpose of this updated medical evidence-based review is to provide a contemporary analysis of anterior and posterior surgical techniques in the treatment of subaxial cervical spinal fractures and dislocation injuries.

ABBREVIATION: AS, ankylosing spondylitis

SEARCH CRITERIA

A National Library of Medicine (PubMed) computerized literature search was performed in a fashion similar to the one that formed the basis of the previous guideline on this topic. The search consisted of publications from 1966 through 2011 using the following headings limited to the English language: "cervical vertebrae," "spinal fractures," and "dislocations," leading to 8684, 5810, and 9450 citations, respectively. The first heading was combined with the second 2 headings, leading to a subset of 1118 and 466 citations, respectively. Another search of "therapeutics" or "treatment" limited to the English language led to 1 870 663 citations. This was combined with each of the 2 prior subsets, leading to 856 citations with abstracts. These abstracts were reviewed, and only

those containing 10 or more cases of subaxial cervical injury after nonpenetrating cervical trauma were included. Twenty-eight articles met the selection criteria and provide the basis for this updated review. They are summarized in Evidentiary Table format (Tables 1-2).

SCIENTIFIC FOUNDATION

Individual subaxial cervical spine injuries represent a wide spectrum of damage to the anatomic structures of the neck, including fractures, ligamentous injury, and disk disruption, often with injury to the cervical spinal cord and nerve roots. Although each injury is unique in terms of the particular complex of bone and soft-tissue disruption, some type of classification is necessary as an intellectual framework to develop consistent treatment algorithms. Some variation of the Allen and Ferguson mechanistic classification system continues to be used as the basis for injury classification.[2] Unfortunately, the complexity of individual injuries, often comprising different types of injuries to multiple segments of the spine, frequently necessitates complex reconstructive strategies. Few clinical series describe a pure population of a single subaxial cervical spinal injury type treated completely uniformly.

Summary of Previous Findings

The previous medical evidence-based guideline on this topic focused on "the utility of closed reduction with or without external immobilization compared to arthrodesis with or without internal fixation." Several generalizations can be distilled from that early medical evidence-based review. Treatment with external immobilization only (traction or orthosis) failed to maintain adequate spinal alignment in approximately 30% of injuries treated in that fashion. Approximately 9% of surgically treated patients had a similar fate. Vertebral compression of 40%, kyphosis of 15%, or vertebral subluxation $> 20\%$ were cited as risk factors for failure of external immobilization. A greater proportion of failed alignment patients had residual cervical pain compared with similarly treated patients in whom anatomic spinal alignment was achieved and maintained. Twenty-six percent of patients failed closed reduction of their cervical facet dislocation injuries, whereas 96% of patients treated surgically (open reduction) achieved successful reduction. Anterior plate fixation and posterior lateral mass plate/screw systems were both highly successful at maintaining spinal reduction and alignment postoperatively. Posterior fusion procedures were associated with a higher rate of complications (37%) than anterior fusion procedures (9%).[1]

Nonsurgical Treatment

Four articles in the current literature review were identified that dealt with the nonsurgical management of subaxial fractures: 3 articles related to unilateral subaxial facet injuries and 1 article related to compressive flexion injuries.

Unilateral facet injuries represent a broad spectrum of potential degrees of mechanical instability. Although the injury to the facet complex itself is often obvious, it can be difficult to determine whether the amount of injury is sufficient to render the spine unstable to the point where external immobilization would likely be inadequate to maintain spinal alignment to facilitate healing. In 1997, Halliday et al[3] studied 24 unilateral facet injuries and evaluated these injuries by magnetic resonance imaging (MRI). Injuries to the anterior longitudinal ligament, posterior longitudinal ligament, facet capsule, and interspinous ligament were studied. Patients were treated both surgically and nonsurgically in their retrospective series. Twelve patients were treated nonsurgically. Six of the 7 treatment failures in this group had 3 of 4 ligaments injured. Eight of 12 surgically treated patients also had at least 3 ligaments injured. Spector et al[4] studied 24 unilateral facet fractures treated nonsurgically. Five of these injuries eventually required surgical stabilization either for loss of position or for the development of radiculopathy. In addition, 4 of 6 patients who presented with radicular complaints had no improvement of their symptoms by the end of the study period. These authors found that fractures involving $\geq 40\%$ of the absolute height of the intact lateral mass or an absolute height of 1 cm were at increased risk for failure of nonoperative treatment. Lee and Sung[5] described 39 patients treated with single-level anterior interbody fusion for unilateral lateral mass fractures. In their cohort study, 15 patients were initially treated nonoperatively. Twelve of these 15 patients eventually required surgical treatment. The authors, however, did not detail the reasons for their nonoperative treatment failures.

In 2002, Fisher and associates[6] reported a retrospective cohort study comparing halo vest immobilization with anterior cervical fusion for the treatment of subaxial cervical compression-flexion (teardrop) fractures. Four of 24 patients treated in a halo device eventually required surgical treatment. The average kyphosis in the halo treatment group was 11.4° compared with 3.5° in the group treated with instrumented anterior fusion (21 patients). However, functional outcome, as judged by Short Form-36 scores, was equivalent between the 2 groups. Although the patients were matched in many respects, because of the retrospective nature of the series and the manner in which treatment was determined (based on the preference of the attending surgeon), this study offers Class III medical evidence.

Anterior Arthrodesis

Proponents of anterior internal fixation and fusion for the treatment of acute subaxial cervical spinal fractures cite several potential advantages of this treatment approach. Patient positioning is safe and straightforward, obviating the need to turn the patient prone with the potential of an unstable injury. The surgical dissection is accomplished along defined tissue planes with little if any iatrogenic muscle injury. Ventral decompression of the spinal cord can be performed under direct visualization. However, anterior screw/plate instrumentation may be biomechanically

inadequate to control instability postoperatively. Several authors have investigated the utility of standalone anterior instrumentation and fusion in the treatment of subaxial cervical spinal injuries.

Woodworth et al[7] performed a retrospective review of 19 patients with a mixture of injury types treated with anterior decompression and fusion. They reported an 88% fusion rate with only 1 instrumentation failure. There were no cases of neurological deterioration and no infections. Kasimatis et al[8] described a series of 74 patients, also with a mixture of injury types. Ninety percent of the patients in their series achieved success fusion. Although they reported 11 postoperative infections (15%), only 3 patients required revision surgery. Reindl et al[9] reported a retrospective series of 41 consecutive patients with "disruptions of both anterior and posterior structures and subluxation or dislocation of at least one facet" treated with anterior instrumented fusion. All patients went on to solid fusion with no loss of reduction or instrumentation failures. One patient experienced a transient neurological deterioration. Six of 19 patients with a spinal cord injury on admission improved at least 1 Frankel grade. Twenty percent of patients had transient dysphagia postoperatively, and 20% had persistent moderate to severe neck pain at last follow-up.

Other authors have reported on anterior internal fixation and fusion more specifically for facet and lateral mass injuries. Lee and Sung[5] described 39 patients treated with a single-level anterior fusion for unilateral lateral mass fractures. Radiographic failure was observed in 8 patients (21%). Three cases had instability or malalignment at an adjacent segment; 5 cases had incomplete reduction of their subluxation injuries. Henriques and associates[10] reported a series of 39 patients with ligamentous unilateral and bilateral facet dislocations treated with anterior instrumentation and fusion. Only 2 of 17 patients with unilateral injuries lost reduction postoperatively. Conversely, 7 of 13 patients with bilateral injuries demonstrated postoperative recurrent subluxation. Although no statistical analysis was performed on this small sample, the authors noted that 4 of 5 patients with complete neurological injuries and bilateral facet dislocations had radiographic failure. Johnson et al[11] published a retrospective series of 87 patients (of 107 total) with unilateral and bilateral facet injuries treated with anterior instrumentation and fusion. Thirteen percent of patients suffered radiographic failure; none had neurological deterioration. Analyzing the 11 patients who suffered a loss of reduction after surgery, the authors identified facet fracture (10 of 11), endplate fracture (9 of 11), and C6-7 injury level (8 of 11) as risk factors for radiographic failure in their experience.

Posterior Arthrodesis

Proponents of posterior fixation and fusion as treatment for subaxial cervical spinal fracture injuries cite superior biomechanics as the primary advantage of this internal fixation strategy. Furthermore, open reduction of facet dislocations is straightforward with the posterior approach and has been the traditional surgical method used. Five contemporary articles reported clinical series of subaxial injuries treated with posterior fixation and fusion. Kotani et al,[12] Zhou et al,[13] and Yukawa et al[14] all reported retrospective series of patients treated with pedicle screw instrumentation for a variety of subaxial injuries. Overall, these series document a low rate of instrumentation-related and other complications and good neurological recovery with this demanding surgical technique. Lenoir and associates[15] reported a series of 30 patients treated with posterior fixation and fusion for fractures around the cervicothoracic junction, an area where instrumentation failure has been felt to be common because of high biomechanical stress. Five patients with similar injuries were also treated with anterior decompression and fusion with internal fixation (dorsal-ventral combination procedure). The postoperative pulmonary infection rate (30%) and mortality rate (23%) were high in patients with these severe high-energy injuries, but the number of instrumentation failures (2) and wound infections (2) was low. Finally, Pateder and Carbone[16] described a series of 29 patients with a mixed series of cervical spinal subaxial injuries treated with posterior lateral mass screw fixation and fusion. Of these 29 patients, only 1 experienced instrumentation failure and 1 suffered a root injury. There were 4 postoperative wound complications. On average, the authors noted a 2° loss of correction in sagittal angulation with posterior operative reduction and internal fixation techniques.

Anterior-Posterior Arthrodesis

Several authors have reported series of patients treated with a combination of anterior and posterior decompression, internal fixation, and fusion techniques. Harrington and Park[17] treated unilateral and bilateral facet injuries with single-level arthrodesis in 22 patients. The authors did not differentiate outcomes between the anterior standalone and anterior and posterior techniques. They reported 68% correction of sagittal angulation and 70% correction of translational deformity for unilateral injuries compared with 51% and 65%, respectively, for bilateral injuries. They identified no nonunions or cases of neurological deterioration. Toh et al[18] reported a retrospective study of 31 patients treated with a variety of surgical techniques (24 anterior, 7 posterior) for a mixture of subaxial cervical spinal injuries (11 burst fractures, 20 teardrop injuries). The group treated with posterior fixation and fusion had higher rates of postoperative spinal canal compromise and required more spinal levels to achieve effective fixation. Bone fragment removal and decompression of the spinal canal were better for patients treated anteriorly compared with those treated posteriorly. Nine of 24 patients treated with anterior surgery improved neurologically, but none of the patients treated posteriorly improved. No Frankel A patient recovered motor function regardless of treatment. Song and Lee[19] compared anterior and combined anterior and posterior internal fixation and fusion techniques in a series of 50 patients with distractive subaxial cervical flexion injuries. They found no differences in the rate of union, complications, or

radiographic or neurologic outcomes. Lambiris et al[20] published a comparative cohort study of patients undergoing either anterior (74 patients) or posterior (23 patients) fixation and fusion for a variety of subaxial cervical spinal injuries. They reported no difference in the complication rates between the 2 techniques.

Brodke and colleagues[21] randomized 52 consecutive patients with unstable subaxial cervical spine injuries to anterior or posterior stabilization and fusion. Injuries in all patients were reduced and decompressed preoperatively by closed reduction; therefore, the choice of surgical approach was not dictated by the need to decompress the spinal canal. The authors found no difference in the neurological outcome, final degree of kyphosis, fusion status, or rate of complications between the 2 surgical approaches. Because of the small number of patients included in this randomized comparative study (inadequate study power), this report provides Class III medical evidence.

Kwon et al[22] performed a prospective randomized trial of unilateral facet injuries comparing anterior with posterior internal fixation and fusion techniques in 42 patients. All injuries were judged to require surgical stabilization by the treating surgeon. Patients with significant vertebral body fractures, disk herniations, or spinal cord injuries were excluded from the trial. The authors found no difference in the primary outcome: time to fulfill criteria for hospital discharge. They also found no difference in postoperative pain scores, 1-year self-reported outcomes measures, or fusion rates. More than 50% of the patients treated with anterior fusion procedures complained of dysphagia, all of which reportedly resolved by 3 months. Four of 22 patients treated with posterior internal fixation and fusion procedures suffered wound complications (1 deep, 3 superficial); none of the 20 patients treated anteriorly had wound complications. Patients treated with posterior procedures had statistically more kyphosis (1.6°) compared with those treated with anterior procedures (8.8° lordosis). Patients treated with plates posteriorly had more kyphosis than those treated with wires, although the plates used were not constrained. Because of the small number of study patients and because the primary study end point was only meeting criteria for hospital discharge, this study was considered to offer Class III medical evidence on this issue.

Ankylosing Spondylitis

In the previous version of the guideline on the treatment of subaxial cervical spinal injuries, the author group noted that comparatively few studies examined the specific difficulties associated with the management of patients with ankylosing spondylitis (AS) who sustain subaxial cervical spinal injuries.[1] Results of the treatment of these patients were rather dismal. In 4 articles reporting patients with this entity and subaxial injuries, 9 of 22 total patients died. Four patients managed nonoperatively died. Two of 9 survivors treated with external immobilization failed treatment. One worsened neurologically when placed in a halo and was subsequently treated successfully with laminectomy and posterior internal fixation and fusion. The other patient had persistent cervical subaxial spinal instability but refused further therapy. In contrast, 5 of 9 AS patients with subaxial cervical fracture injuries treated primarily with surgery died. One patient was neurologically worse after surgery. Three patients healed successfully without instability.[23-25]

Four additional reports concerning the care of patients with AS and subaxial cervical spinal injuries were identified in the current literature search. Cornefjord et al[26] published a retrospective case series (Class III medical evidence) of 19 patients with AS and subaxial cervical spine fractures treated with posterior fixation and fusion. Four patients were also treated with anterior fusion procedures. Five patients died during the follow-up period, but no deaths were related to surgery. All patients sustained fractures after low-energy trauma. One patient deteriorated neurologically postoperatively. Two of 8 patients with neurological deficits improved postoperatively. There were no cases of instrumentation failure or loss of reduction. The authors concluded that long-segment rigid posterior fixation was an acceptable method for treating patients with AS who sustained subaxial cervical spine fractures.

Einsiedel and colleagues[27] described a retrospective review of 37 AS patients with subaxial fractures from 2 institutions over a 16-year period. All patients were treated surgically. Ten patients were treated with anterior standalone instrumentation and fusion. Twenty-four patients were treated with anterior and posterior instrumentation and fusion. Two cases were treated with posterior instrumentation and fusion alone, and 1 patient underwent laminectomy only without fusion. Patients were followed up only until hospital discharge. All patients improved neurologically. Despite the short-term follow-up, 50% of patients treated with anterior instrumentation suffered instrumentation failure. No patient treated with posterior instrumentation experienced instrumentation failure. Three patients died in the early postoperative period. The authors noted a high rate of fractures detected with only computed tomography or MRI in the thoracic and lumbar regions in association with the primary subaxial cervical fractures. From this class III medical evidence, the authors concluded that cervical spinal fractures in patients with AS should be treated with combined anterior and posterior instrumentation and fusion procedures.

In 2008, Kanter and colleagues[28] published a series of 13 patients with AS and subaxial cervical fractures. Twelve patients had either posterior standalone instrumentation and fusion or anterior and posterior surgery. Only 1 patient underwent anterior-only instrumentation and fusion. An average of 5.6 segments were instrumented. Five of 13 patients improved neurologically; 1 patient had neurological deterioration. Thirty-eight percent of the patients experienced complications, including instrumentation failure in 2 patients and death in 1 patient. All of the 10 patients available for radiographic follow-up went on to achieve fusion confirmed by computed tomography imaging. The authors offered a complex management algorithm and recommended surgical treatment for all patients with AS and cervical fractures. This study represents Class III medical evidence on this issue.

TABLE 1. Evidentiary Table: Treatment of Subaxial Injuries

Reference	Fracture Type	Description of study	Evidence Class	Conclusions
Zhou et al,[13] *Annals of the Royal College of Surgeons of England*, 2010	Mixed	Retrospective review of 48 patients treated with pedicle screw instrumentation	III	18 of 20 incomplete injuries improved. No neurological deterioration, no instrumentation failure, no pseudoarthrosis.
Kasimatis et al,[8] *Clinical Neurology and Neurosurgery*, 2009	Mixed	Cohort study of 74 patients treated with anterior surgery	III	90% fusion rate. 11 postoperative complications. 3 revision surgeries. 4 mortalities.
Lee and Sung,[5] *Journal of Trauma*, 2009	Lateral mass	Retrospective review of 39 patients treated with single-level anterior cervical diskectomy and fusion	III	12 of 15 patients treated in an orthosis require late surgery. 6 cases of persistent radiculopathy.
Woodworth et al,[7] *Journal of Neurosurgery: Spine*, 2009	Mixed	Retrospective review of 19 patients treated with anterior cervical diskectomy and fusion	III	88% fusion rate. 1 instrumentation failure. Average Neck Distensibility Index = 6.5 $\pm$ 2.9. No neurological deterioration. 10 of 11 radiculopathies resolved. No wound infections.
Yukawa et al,[14] *European Spine Journal*, 2009	Mixed	Retrospective study of posterior fixation with pedicle screws	III	13% screw malposition. 1 radiculopathy. 1 vertebral artery injury. 5 loss of correction. 4 deep infections.
Lambiris et al,[20] *Journal of Spinal Disorders and Techniques*, 2008	Mixed	Comparative cohort study of anterior and posterior fixation	III	No difference in complications between either group.
Song and Lee,[19] *Journal of Clinical Neuroscience*, 2008	Distractive flexion	Retrospective comparative study of anterior vs anterior-posterior fixation in 50 patients	III	No difference in union, radiographic or neurological outcome, or complications.
Harrington and Park,[17] *Journal of Spinal Disorders and Techniques*, 2007	Unilateral and bilateral fractures	Prospective cohort study of 22 patients treated with anterior or anterior-posterior instrumentation	III	No neurological worsening, 1 wound infection, no nonunions. 51% sagittal angulation, 65% translational correction for bilateral injuries. 68% sagittal angulation, 70% translational correction for unilateral fracture injuries.
Kwon et al,[22] *Journal of Neurosurgery: Spine*, 2007	Unilateral facet injuries	Prospective randomized trial of 42 patients with unilateral facet injuries without spinal cord injury, disk herniation, or vertebral body fracture judged unstable by treating surgeon	III	No difference in hospital stay, postoperative neck pain or 1-y self-reported health-related quality of life measures or fusion rate. 11 of 20 anterior patients had dysphagia (all resolved by 3 months). 4 of 22 posterior patients with wound complications vs 0 of 20 anterior patients. Lateral mass plates had more kyphosis. Insufficient study numbers.
Lenoir et al,[15] *Spine Journal*, 2006	Cervical-thoracic junction fractures	Retrospective review of 30 patients treated with posterior fixation	III	Mortality: 7 of 30. Neurological recovery: 9 of 30. Neurological deterioration: 1 of 30. Pulmonary infection: 30%. 2 instrumentation failures. 2 wound infections.
Pateder and Carbone,[16] *Spine Journal*, 2006	Mixed	Retrospective review of 29 patients treated with lateral mass screws	III	1 instrumentation failure. 1 root injury. 2° average loss of correction. 4 wound complications.
Reindl et al,[9] *Spine* 2006	Facet injuries	Retrospective review of 41 consecutive patients treated with anterior cervical diskectomy and fusion	III	No instrumentation failure, loss of reduction or pseudoarthrosis. 1 neurological deterioration. 5 patients with persistent moderate to severe neck pain.

(Continues)

TABLE 1. *Continued*

Reference	Fracture Type	Description of study	Evidence Class	Conclusions
Spector et al,[4] *Spine*, 2006	Unilateral facet fractures	Retrospective study of 24 patients treated nonsurgically	III	5 patients required surgical stabilization, loss of position (4), progressive radiculopathy (1). 4 of 6 patients with radiculopathy had persistent symptoms at the end of treatment. Unilateral cervical facet fractures involving 40% of the absolute height of the intact lateral mass or an absolute height of 1 cm are at increased risk for failure of nonoperative treatment.
Toh et al,[18] *International Orthopaedics*. 2006	Compressive flexion	Retrospective study of burst and teardrop fractures treated either anteriorly or posteriorly	III	Patients treated with anterior surgery had better decompression and better neurological recovery than those who received posterior surgery alone.
Kotani et al,[12] *European Spine Journal*, 2005	Lateral mass fractures	Retrospective review of 31 patients treated with pedicle screw fixation	III	6 of 31 residual malalignment, no pseudoarthrosis. 0% neurological deterioration. All myelopathy improved. 3 of 21 with residual radiculopathy. 1 deep infection, 1 instrumentation removal.
Henriques et al,[10] *Journal of Spinal Disorders and Techniques*, 2004	Distractive flexion	Retrospective review of 39 patients treated with anterior cervical diskectomy and fusion	III	2 of 17 unilateral injuries with nonunion. 7 of 13 bilateral injuries lost reduction.
Johnson et al,[11] *Spine*, 2004	Distractive flexion	Retrospective review of 87 (of 107) patients treated with anterior single-level fusion	III	13% failure rate (11 of 87): 8 of 11 at C6-7, 10 of 11 facet fracture, 9 of 11 endplate fracture. No neurologic deterioration
Brodke et al,[21] *Journal of Spinal Disorders and Techniques*, 2003	Mixed subaxial fractures	Randomized consecutive series of 52 patients with unstable injuries and spinal cord injury treated with either anterior or posterior surgery	III	No difference in neurological outcome, kyphosis, fusion status, or complications. Insufficient study numbers, inadequate power.
Fisher et al,[6] *Spine*, 2002	Subaxial cervical fractures (teardrop)	Retrospective cohort comparing anterior cervical fusion (21 patients) and Halo vest (24 patients).	III	4 of 24 Halo patients failed. Average final kyphosis: 11.4° in the halo group, 3.5° in the anterior cervical fusion group. No difference in Short Form-36 scores.
Halliday et al,[3] *Spine*, 1997	Unilateral facet fracture	Retrospective review of 24 unilateral facet fractures evaluated by magnetic resonance imaging	III	6 of 7 nonsurgical treatment failures had at least 3 of 4 ligaments injured. 8 of 12 patients managed surgically had at least 3 of 4 ligaments injured.

In 2010, Caron et al[29] published a retrospective review of their experience treating patients with AS or diffuse idiopathic skeletal hypertrophy syndrome who had sustained spinal fractures. One hundred twelve patients were identified in their database. Clinical and radiographic follow-up was available for 62 of 84 patients who survived the initial hospitalization with a mean follow-up of 6.5 months. Sixty-seven fractures (55%) were in the cervical spine. The authors did not quantify their results by spinal level. Neurological deterioration occurred in 81% of patients for whom there was a delay in diagnosis (19% of all patients). The reported overall mortality was 32%. Mortality was significantly higher (P = .005) in patients treated nonsurgically, but some of these patients were not treated surgically because of their severe medical comorbidities. Linear regression analysis revealed that age was the primary predictor of mortality in their review. The authors concluded that patients with AS and those with diffuse idiopathic skeletal hypertrophy who sustained traumatic spinal fractures were sufficiently similar to be considered together in terms of treatment and prognosis. Extreme vigilance and the routine use of advanced imaging (computed tomography and MRI) were recommended because of the significant number of patients who presented with a delayed diagnosis and neurological deterioration.

SUMMARY

Subaxial cervical spine fractures and dislocations encompass a broad spectrum of acute traumatic injuries. Adequate decompression of the neural elements and the restoration of sufficient spinal stability to allow early mobilization and rehabilitation remain basic treatment tenets. Although nonsurgical treatment

TABLE 2. Evidentiary Table: Treatment of Subaxial Injuries Ankylosing Spondylosis

Reference	Description of study	Evidence Class	Conclusions
Caron et al,[29] *Spine*, 2010	Retrospective cohort study of 62 (of 84) patients with spinal fractures and ankylosing disorders	III	8% noncontiguous fractures. 19% delay in diagnosis (81% of these with neurological deterioration). 32% overall mortality. Age best predictor of mortality.
Kanter et al,[28] *Neurosurgical Focus*, 2008	Retrospective review of 13 ankylosing spondylitis patients treated surgically	III	1 of 13 neurological deterioration. 5 of 13 neurological improvement. 38% complications. 1 mortality.
Einsiedel et al,[27] *Journal of Neurosurgery: Spine*, 2006	Retrospective study of 37 patients with ankylosing spondylitis treated surgically	III	16% multilevel injury. 35% delayed diagnosis. 50% failure rate in anterior only instrumentation. All patients improved neurologically.
Cornefjord et al,[26] *European Spine Journal*, 2005	Retrospective review of Olerud pedicle screw-rod system. 19 ankylosing spondylitis patients	III	0% mortality. 0% instrumentation failure/loss of reduction. 1 deep wound infection.
Weinstein et al,[23] *Journal of Neurosurgery*, 1982	Retrospective study. 13 ankylosing spondylitis: 7 traumatic cervical, 6 quadriplegic, 2 central cords without fracture	III	2 treated with traction died of pneumonia. 2 treated with traction/brace healed. 1 worse halo, treated surgically. 1 laminectomy/fusion worse. 1 laminectomy/fusion had pseudoarthrosis.
Bohlman,[24] *Journal of Bone and Joint Surgery: American Volume*, 1979	Retrospective study; 300 cervical injuries; 8 ankylosing spondylitis patients	III	5 of 8 patients died. 2 healed after brace treatment and 1 after laminectomy.
Cheshire,[30] *Paraplegia*, 1969	Retrospective study; 257 cervical injuries; 1 ankylosing spondylitis patient	III	1 C5-C6 extension injury healed with surgical fusion.
Grisolia et al,[25] *Journal of Bone and Joint Surgery: American Volume*, 1967	Retrospective study of 6 ankylosing spondylitis patients	III	3 of 4 healed with brace ± traction. 2 with laminectomy and posterior cervical fusion died of pulmonary embolism.

can be employed successfully, surgical treatment of these injuries achieves these goals more consistently and more quickly, especially in higher grades of injury. Both anterior and posterior surgical approaches have been reported as effective. Neither approach is necessarily superior to the other as long as the goals of treatment can be accomplished. Treatment must be individualized on the basis of the specific characteristics of each particular injury. Factors to be considered include neurologic status, the degree and type of bony and/or ligamentous disruption, and the degree and cause of spinal cord compression. The treatment of patients with AS who sustain traumatic subaxial cervical spinal fractures is challenging and has a comparatively high associated morbidity and mortality, regardless of the treatment offered or the surgical approach used.

KEY ISSUES FOR FUTURE INVESTIGATION

Subaxial cervical spine injuries are common, can have devastating personal consequences, and represent a significant cost to individuals and society. Research continues to be hampered by lack of an accurate, reproducible, universally accepted classification system. Recent literature continues to suffer from poorly characterized patient populations, inconsistent treatment protocols, and variable outcome measures that make generalizations regarding treatment difficult. Only 2 prospective Class I trials in investigation of these injury types were identified in the present literature review; unfortunately, both provided Class III medical evidence because of inadequate power and other study design or process factors. Future research needs to incorporate more precisely characterized patient groups, more rigorously defined treatment protocols, and generalizable outcome measures obtained by complete, comprehensive follow-up.

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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