A treatment algorithm for the management of cervical spine fractures and deformity in patients with ankylosing spondylitis

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Object. Patients with ankylosing spondylitis (AS) who present with cervical spine fractures represent a unique challenge to spine surgeons. These injuries often result in neurological deficits that necessitate early and aggressive surgical management with posterior and/or anterior fixation. The authors introduce a clinical problem-solving algorithm to assist in the surgical management of instability and deformity in this exigent patient population.

Methods. Thirteen patients with AS and fractures of the cervical spine were radiographically evaluated to determine if spinal realignment was obtainable with cervical manipulation or traction. Seven patients had flexible deformities that were stabilized with either anterior or posterior fixation only, and 6 patients had fixed deformities and required circumferential anterior-posterior instrumentation. All patients were observed for neurological outcome, radiographic evidence of bone fusion, and complications.

Results. With the use of the authors' treatment algorithm, all patients were able to achieve satisfactory spinal realignment and bone fusion; 92% of patients achieved postoperative stability or improvement in Nurick and modified Japanese Orthopaedic Association scale scores. One patient experienced neurological deterioration following surgery, and 1 patient died at an acute rehabilitative facility following discharge.

Conclusions. Patients with AS are highly susceptible to extensive neurological injury and spinal deformity after sustaining cervical fractures from even minor traumatic forces. These injuries are uniquely complex in nature and require considerable scrutiny and aggressive surgical management to optimize spinal stability and functional outcomes. The authors' clinical problem-solving algorithm will assist spine surgeons in providing optimal care in this difficult population. (DOI: 10.3171/FOC.2008.24.1.E11)

KEY WORDS • ankylosing spondylitis • cervical • deformity • fracture • kyphosis

ANKYLOSING spondylitis is a seronegative, progressive, systemic, inflammatory rheumatic spondyloarthropathy mainly affecting the spine and sacroiliac joints. Ankylosing spondylitis is the third most common arthritic condition in the United States and involves an *HLA-B27* genetic predisposition in the majority of cases.^{7,45} The disease is characterized by a diffuse inflammatory reaction resulting in ossification of spinal ligaments, joints, and intervertebral discs. Over time, the once dynamic and flexible spinal column becomes a rigid and deformed lever arm, increasingly susceptible to major traumatic injury from minor forces.^{6,12,33} This leads to decreased functionality and progressive osteoporosis thus increasing the risk of fracture and deformity.^{5,14,25}

Patients with AS represent a unique challenge to spine

surgeons when presenting with a cervical spine fracture; the majority of these fractures occur at the level of the intervertebral disc and result in anatomic displacement and instability.^{18,19,22,31} These injuries often result in neurological deficits that necessitate early and aggressive surgical management with posterior and/or anterior fixation techniques to enable neural decompression, spinal stability, and optimal functionality.^{6,13}

Several reports have been published describing an array of surgical techniques to treat these fractures and their resulting deformities,^{10,11,16,43} yet no standardized treatment algorithm exists that approaches this challenging pathological entity in a systematic, logical, and concise manner. We aim to introduce a clinical problem-solving algorithm that incorporates both neurological status and spinal deformity variables to establish optimal surgical management methodically in this exigent patient population.

Clinical Material and Methods

We retrospectively reviewed the cases in a series of pa-

Abbreviations used in this paper: AS = ankylosing spondylitis; ASF = anterior segmental fixation; CT = computed tomography; ICBG = iliac crest bone graft; mJOA = modified Japanese Orthopaedic Association; PSF = posterior segmental fixation.

FIG. 1. Flow chart of the proposed algorithm for the management of neurological injury (A) and spinal deformity (B) in patients with AS and cervical spine fractures.

tients with traumatic cervical fractures and spinal deformity in conjunction with AS who were treated by 2 spine surgeons (P. M. and M. W.) over a 5-year period (2003–2007). Thirteen patients (9 men and 4 women) between the ages of 47 and 83 years (mean 60.4) were included in this cohort.

The problem-solving algorithm illustrated in Fig. 1 was utilized to determine surgical management decisions. Fracture site and pattern, facet pathology, degree of dislocation, cord compression, and deformity were noted. Neurological deficits were classified according to the mJOA³ and Nurick scales.³⁰ Surgical urgency was determined by neurological status; patients with incomplete injuries with spinal cord compression were treated urgently (within 24 hours) and those with complete and central cord injuries were stabilized medically and treated with delayed surgery.

All patients were evaluated radiographically with plain films, CT, and magnetic resonance imaging studies. Com-

puted tomography scans were used to elucidate the bone detail of the fracture, deformity, and surrounding fixation sites, and magnetic resonance imaging studies to provide ligamentous detail and reveal any complicating factors that might mitigate or amplify surgical urgency (such as an epidural hematoma). Radiography was used to determine if spinal realignment was attainable with gentle cervical manipulation. Acutely injured patients without significant spinal deformity were treated with ASF or PSF, depending on fracture location. Acutely injured patients with spinal deformity, and all patients with delayed injuries, underwent light cervical traction-reduction measures to optimize spinal alignment prior to surgical intervention.

Patients with fractures that could be successfully reduced with light traction underwent PSF, whereas those whose fractures did not reduce required intraoperative reduction measures. The patients in the latter category with anterior bone apposition received an anterior approach for spinal

Treatment algorithm for management of cervical spine fractures

TABLE 1

Summary of clinical data obtained in 13 patients with AS and cervical spine fractures with deformity

Case No.	Age (yrs), Sex	Fracture Site	Type of Deformity
1	81, M	C6–7	acute
2	55, M	C5–6	acute
3	47, F	C4–5	acute
4	53, F	C7–T1	acute
5	49, F	C6–7	acute
6	53, M	C7–T1	chronic
7	60, F	C6–7	acute
8	60, M	C6–7	chronic
9	63, M	C6–7 & C7–T1	chronic
10	67, M	C7–T1	acute
11	66, M	C7–T1	acute
12	83, M	C7–T1	acute
13	48, M	C6–7	acute

realignment if the anatomical access permitted, otherwise a posterior approach was performed followed by either anterior wedge osteotomy or osteoclasts and PSF.

Patients were monitored for neurological outcome, radiographic fusion, and complications. Complications were categorized into general (such as infection, dysphagia, or death) and surgical (such as instrumentation failure) subtypes. Postoperative follow-up examinations were performed at intervals of 6 weeks, 6 months, and annually thereafter, with radiographic evaluations including CT scans obtained immediately postoperatively and again at the 6 and 12 month follow-up examinations. Dynamic flexion–extension radiographs were performed at all follow-up visits.

Results

Clinical data are summarized in Table 1. Ten (77%) of the 13 fractures were acute injuries and 3 (23%) were chronic in nature. Twelve fractures (92%) involved 1 cer-

TABLE 2

Summary of surgical data in 13 patients with AS and cervical spine fractures with deformity*

Case No.	Surgical Approach	Fixation Level	Graft Materials
1	A/P	C4–T2	fibula & local bone
2	A/P	C3–6	fibula & local bone
3	A/P	C3–6	fibula & ICBG
4	P	C4–T4	ICBG
5	P/A	C4–T3	PEEK & ICBG
6	A	C7–T1	PEEK & local bone
7	A/P	C5–T2	PEEK & local bone
8	A/P	C4–T2	fibula & local bone
9	P	C6–T3	local bone
10	P	C4–T2	ICBG
11	P	C6–T2	ICBG
12	P	C3–T2	local bone
13	P	C4–T2	ICBG

* A = anterior only; P = posterior only; A/P = 2 stages: anterior, then posterior; P/A = 2 stages: posterior, then anterior. Abbreviation: PEEK = polyetheretherketone.

vical segment, and 1 (8%) involved 2 levels. The most frequently injured levels were C6–7 and C7–T1 (in 85% of patients). One patient (8%) suffered a concomitant epidural hematoma necessitating urgent surgical evacuation in addition to the stabilizing procedure.

Surgical data are summarized in Table 2. Six patients (46%) with flexible deformities were stabilized with posterior fixation only, and 1 patient (8%) underwent a sole anterior fixation procedure. The remaining 6 patients received circumferential fixation, 5 (38%) via an anterior approach followed by posterior instrumentation, and 1 (8%) via posterior stabilization prior to anterior fixation. An average of 5.6 segments were instrumented in each case with harvesting of ICBG material in 6 patients (46%); all others received autogenous local bone graft obtained from the spinous processes and lamina. A fibular interbody allograft was utilized in 4 of the anterior procedures, polyetheretherketone cages filled with morselized autogenous bone was

FIG. 2. Preoperative plain radiograph (A) and CT scan (B) showing C6–7 fracture dislocation in the patient in Case 5. Postoperative plain radiography study obtained at the 1-year follow-up examination (C) showing successful spinal realignment and fusion with anterior–posterior instrumentation.

used in 3. Representative pre- and postoperative imaging studies obtained in a patient who underwent typical anterior-posterior fixation are shown in Fig. 2.

Figure 3A and B graphically depicts pre- and postoperative neurological status as classified using the Nurick³⁰ and mJOA scales.^{1,3} Twelve of the 13 patients either maintained stability or experienced improvement in their neurological deficits after surgical intervention. One patient suffered deterioration in neurological status, climbing 1 level on the Nurick scale and dropping 1 level on mJOA classification. The remaining patients improved an average of 0.9 on the mJOA scale (8.8 to 9.7). One patient improved by 5 grades, 2 patients by 3 grades, and 2 patients by 1 grade. Seven patients' conditions remained unchanged.

General and surgical complications are summarized in Table 3. Five (38%) of the 13 patients suffered sequelae. Two patients required repeated operations because of hardware failure (screw pullout and graft/plate migration; Fig. 4). One experienced severe dysphagia secondary to intraoperative esophageal manipulation, which required the placement of a percutaneous endoscopic gastrostomy tube for a 2-month period until adequate improvement in swallowing allowed for its removal. One patient suffered permanent loss of vision following surgery in the prone position, and 1 patient died of an aspiration event in a rehabilitation facility 2 months postoperatively.

Of the 12 surviving patients, 10 achieved radiographic fusion confirmed by CT scan (2 patients were lost to radiographic follow up). The average postoperative follow-up period was 12.8 months (range 3–22 months).

Discussion

In the present study, 13 patients with AS and cervical fractures received treatment according to the problem-solving algorithm depicted in Fig. 1. There were 4 complications and 1 death, yielding a 38% complication and mortality rate in this challenging patient population; this rate is similar to the rates reported in other series.^{13,14,27}

Neurological deterioration and/or spinal deformity are indications for surgical realignment, fixation, and/or spinal decompression. In the absence of deficit or deformity, attempts have been made to manage the care of these patients nonsurgically, yielding adverse outcomes and neurological sequelae.^{1,4,8,12,22,31,32,37} Progressive neurological injury secondary to delayed dislocation at the original fracture site has been found in as many as 60% of cases managed conservatively.^{4,14,48} Other complications following nonsurgical efforts include infection, skin ulceration (from pressure

FIG. 3. Bar graphs of pre- and postoperative Nurick grades (A) and mJOA scale scores (B) in 13 patients with AS.

sores under hard collars), fracture nonunion, and pulmonary impairment caused by the intrinsic limitations in chest wall expansion and reduced vital pulmonary capacity in AS patients.^{2,21,33,34,47} For these reasons we recommend surgical fixation measures in all parts of the treatment algorithm. The most frequently injured cervical segments in this series were C6–7 and C7–T1 (in 86% of patients), a finding congruent with other studies in the literature,^{18,20–22,28,31,46} and commonly necessitating fusion across the cervicothoracic junction. The authors of several studies have reported realignment and stability of cervical fractures with fixation approach dependent on fracture site and loca-

TABLE 3
Summary of complications*

Case No.	Complication	Action Taken
1	patient died in rehabilitation	none
5	posterior hardware failure (screw pullout), wound infection, & incarcerated bowel	repeated operation, wound washout, & laparotomy
7	interbody graft & plate migration secondary to new fracture at inferior aspect of construct	repeated operation, additional corpectomy w/ expansion of interbody graft & plate
9	dysphagia secondary to esophageal manipulation	PEG placement for 2 months
10	blindness following prone positioning surgery	none

*Abbreviation: PEG = percutaneous endoscopic gastrostomy.

FIG. 4. Plain x-ray films revealing posterior instrumentation failure (screw pullout) obtained in the patient in Case 5. The patient subsequently underwent 360° circumferential fixation.

tion; anterior fractures were treated anteriorly, posterior fractures posteriorly, and circumferential 3-column injuries via 360° fixation. Single-stage 360° fusion in the medically stable patient avoids the added risk of multiple anesthetic interventions, although at the cost of a slightly higher risk of infection.⁴¹

Regardless of surgical technique, patients with AS are predisposed to a dramatically increased risk of surgical complications as evidenced by the present surgical series and others.^{1,14–16} These complications include an increased risk of epidural hematoma and generalized bleeding^{17,44} and instrumentation pullout from osteoporotic bone subjected to long lever arm forces.^{5,15,26,36} Implant failure occurred in 2 patients (15%), both of whom required repeated operations for hardware replacement. Repeated operation imparts additional risk of complications given that it often entails expansion of instrumentation to at least 1 additional uninjured segment.²⁹

Attempts to realign the displaced cervical spine in patients with AS must initially be focused on restoring the original sagittal curvature of the patient's diseased state prior to the fracture. We recommend that surgical decompression be performed urgently in patients with incomplete cord injuries, whereas those with complete or central cord injuries can be treated in a delayed fashion (Fig. 1A).

Acute injuries without spinal deformity can be managed with either ASF or PSF, depending on the injury site. Patients who present with spinal deformity, as well as those with delayed injuries, should be placed in light cervical traction (< 5 lbs) to attempt fracture reduction and spinal realignment. We typically avoid traction weights over 5 lbs because sudden, uncontrolled distraction of the cervical spine may occur with heavier weights. If anterior bone apposition is accomplished, PSF can be performed, with a second stage ASF if there is persistent spinal deformity. If anatomic access is limited because of a pronounced deformity (such as chin on chest), prolonged cervical traction (several days in an intensive care unit with low traction weight) and/or an anterior wedge release via osteotomy or osteoclasis can be performed, followed by PSF to restore cranio-cervical alignment (Fig. 1B). This osteotomy technique has been previously reported by the senior author,²⁷ and its functional significance includes restoration of natural horizontal gaze as emphasized by Suk et al.⁴² and others.¹³

If cervical osteotomies are required, they are preferentially performed at C-7 and T-1 due to the absence of the vertebral artery in the foramen transversarium and the enlarged spinal canal at these levels. Additionally, if iatrogenic spinal cord injury did occur at or below C-7, at least partial upper extremity function would be preserved. Simmons^{39,40} initially described the cervical posterior wedge osteotomy technique that he performed with the patient in the awake sitting position without posterior instrumentation. Mehdian and colleagues²⁵ were among the first to expand on Simmons' technique with the incorporation of posterior instrumentation to avoid sudden spinal subluxation during the correction maneuver and to avoid the use of postoperative halo immobilization.

McMaster²⁴ reported on his experience in performing 15 C7–T1 wedge osteotomies in patients with AS. He obtained a mean kyphosis correction of 54° with restoration of lordosis in all cases, but at the expense of a relatively high complication rate including 2 patients with C-8 nerve root palsies, 4 with progressive subluxations, 2 with pseudoarthroses, and 1 patient with quadriplegia. Several authors of more recent studies have reported similar findings with unique variations in technique to minimize complications and maximize deformity correction. These include the use of transcranial electrical stimulated motor-evoked potential monitoring²³ and controlled intraoperative extension osteotomy on a Jackson table.⁹

Four patients in the present study suffered fractures that were complicated by delayed chin-on-chest deformities. Two patients were successfully extended with preoperative awake halo traction (Fig. 5), a third underwent reduction with manual traction in the operating room while in a state of general anesthesia with neurological monitoring, and the fourth received bone osteoclasis from C6–T1. Two patients subsequently underwent PSF and 2 patients underwent 360° fusion with successful deformity correction and fusion without neurological sequelae.

Injuries that cannot be reduced with traction preoperatively can be addressed via open reduction maneuvers (with or without osteotomies). Open reduction can be performed with spinous process leverage traction on the dislocated facet posteriorly, or with bur excision of the facet complex if gentle traction is unsuccessful.³⁸ Rigid internal fixation is then performed with the goal of limiting fused levels, but not at the expense of a solid construct. In patients with AS this often involves the inclusion of several segments cephalad and caudal to the fracture site. The present study included an average of 5.6 levels of spinal fusion per patient (range 2–8 levels).

Posterior instrumentation in the cervical spine is usually placed into the lateral mass complex secondary to the small pedicle size and encasement of the often aberrant vertebral artery. Thoracic spine hardware is typically placed in a transpedicular fashion under fluoroscopic guidance. Given the anatomic bone distortion secondary to the underlying disease process, the typical landmarks are often obscured, making hardware placement a unique challenge in patients with AS. Detailed knowledge and familiarity with lateral mass and pedicle anatomy is essential for the extrapolation of limited recognizable landmarks during hardware placement and trajectory infiltration.

Posterior instrumentation must be supplemented with bone graft material to insure construct and fusion longevi-

FIG. 5. Images obtained in the patient in Case 8 with C6–7 fracture and chin-on-chest deformity. Photograph obtained at admission (A) and after correction with halo traction (B). Preoperative (C) and postoperative (D) plain radiography after anterior–posterior C-7 corpectomy and C4–T2 posterior fixation.

ty. This is typically performed with local bone harvested from the spinous processes or lamina, rib autograft, or iliac crest autograft. Several series have documented successful fusions with the use of the aforementioned materials, although ICBG has historically shown the greatest structural integrity and remains the gold standard for successful fusion supplementation. Additionally, the use of ICBG avoids the potential complications of rib graft harvesting, which include damage to the neurovascular bundle and pleural cavity.^{1,18,35} However, the ICBG harvest site is commonly identified as a significant pain source in the immediate postoperative period, thus limiting early mobilization and increasing the risk of stasis sequelae (such as deep venous thrombosis). In the present study, 6 patients (46%) underwent ICBG harvesting for fusion supplementation. To date, progressive bone fusion on CT scanning has been revealed in all patients with > 6 months of follow-up, but long-term follow-up is needed to ascertain the efficacy of ICBG over alternative graft substitutes.

Conclusions

Patients with AS are highly susceptible to extensive neurological injury and spinal deformity after cervical frac-

tures caused by even minor traumatic forces. These injuries are uniquely complex in nature and require considerable scrutiny and aggressive surgical management to optimize spinal stability and functional outcomes. We propose the aforementioned clinical problem-solving algorithm to systematically assist spine surgeons in their efforts to provide optimal surgical management in this difficult patient population.

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