Surgical management of global sagittal deformity in ankylosing spondylitis

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ankaexisting spondylitis (AS) is an inflammatory rheumatic disease whose primary effect is on the axial skeleton, causing sagittal-plane deformity at both the thoracolumbar and cervicothoracic junctions. In the present review article the authors discuss current concepts in the preoperative planning of patients with AS. The authors also review current techniques used to treat sagittal-plane deformity, focusing on pedicle subtraction osteotomy at the thoracolumbar junction, as well as cervical extension osteotomy at the cervicothoracic junction. (DOI: 10.3171/FOC/2008/24/1/E8)

KEY WORDS • ankylosing spondylitis • kyphosis • pedicle subtraction osteotomy • sagittal deformity • Smith–Petersen osteotomy

A nkkylosing spondylitis is an inflammatory rheumatic disease primarily affecting the axial skeleton. This continued inflammatory disease process leads to a progressive rigidity of the entire spine. Clinical criteria for diagnosing AS include low-back pain and stiffness of greater than 3 months’ duration and restriction of lumbar motion in both the sagittal and frontal planes. This restriction coupled with an often present thoracolumbar kyphotic deformity can lead to sagittal-plane imbalance. In a longitudinal observational cohort, 49% of patients with AS for a mean duration of 9 years suffered a kyphotic deformity affecting their sagittal balance.

The kyphotic deformity resulting from AS causes a downward and forward shift of the patient’s trunkal center of mass. Because the patient’s other spinal segments cannot move to compensate, the patient’s lower extremities are utilized to maintain the body’s center of mass balance. This may include extension of the hips, flexion of the knees, and plantar flexion of the ankles. This compensation leads to great stress on the involved joints and may insufficiently counterbalance the deformity. This disease primarily affects young men, and the disability from the resulting sagittal-plane imbalance is a significant burden.

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Preoperative Planning

To determine if a patient with sagittal imbalance will benefit from surgery, one should undertake a detailed examination of anterior and lateral photographs as well as anteroposterior and lateral long-cassette radiographs. The CBVA is defined as the angle subtended by a vertical reference line and a line drawn parallel to the chin and brow with the neck in neutral or fixed position and the knees and hips extended. The CBVA is a clinical measurement of the total sagittal deformity of the spine and the effect on horizontal gaze. Sagittal spinal balance is defined from the cervicothoracic spine to the sacrum or hip axis. The C7–S1 sagittal vertical axis is defined as the horizontal distance from a vertical plumb line centered in the middle of the C-7 VB to the posterosuperior corner of the S-1 endplate. The T1–HA sagittal tilt angle is defined as the angle subtended by a vertical reference line through the HA and a line drawn from the midpoint of the T-1 VB to the HA. The T9–HA sagittal tilt angle is defined as the angle subtended by a vertical reference line through the HA and a line drawn from the midpoint of the T-9 VB to the HA.
The sacral endplate angle can be informative as to a patient’s further ability to compensate. The sacral endplate angle, normally 40° with the horizontal, is decreased by the hip extension of a patient with AS compensating for a kyphotic deformity. Therefore, a lower value for the sacral endplate angle is indicative of a greater inability to compensate for a progression of sagittal imbalance. Flexion deformities at the hips may also contribute to the global sagittal deformity in patients with AS. This may be overcome by soft-tissue release and hip replacement in certain patients and should be investigated if present.

Correction of Thoracolumbar Kyphotic Deformity in AS

There are mainly 3 different methods used to treat thoracolumbar kyphotic deformity in patients with AS: opening wedge osteotomies (also commonly described as SPOs), polysegmental wedge osteotomies, and PSOs. These techniques represent an evolution of surgical techniques that have been modified with time to help reduce morbidity and mortality while enhancing the correction of thoracolumbar deformity.

Originally introduced by Smith and Petersen, opening wedge osteotomies involved 2- and 3-level osteotomies through articular processes of L-1, L-2, and L-3 with undercutting of adjacent spinous processes. This was followed by extension of the lumbar spine to close the posterior wedge osteotomies. Although it achieved the correction of kyphosis, this manipulation resulted in disruption of the anterior longitudinal ligament and an anterior monosegmental opening wedge. Furthermore, the anterior column in this technique had inevitable elongation, which was thought to result in significant vascular and neurological morbidity (Fig. 1). One can expect to obtain 5–10° of correction with each SPO. It is important to note that SPOs are frequently inadequate to treat AS deformity corrections if the spine is rigid anteriorly. Because during the closure of the osteotomy an opening of the spine is created anteriorly through the disc space, patients who undergo this procedure are at a high risk of developing pseudarthrosis.

In an attempt to develop a technique to cause less disruption of the anterior column, the polysegmental wedge osteotomy technique was developed. In this technique, wedges of bone are removed from the interlaminar space and the inferior and superior articular processes. By closing these multiple wedges in the posterior column, a more gradual correction of the kyphosis is achieved without disruption of the anterior longitudinal ligament (Fig. 2). In combination with internal fixation with pedicle screws, this technique has been successful in treating kyphotic sagittal imbalance.

Both the SPO and polysegmental osteotomy do not require the surgeon to osteotomize the anterior column. Another viable option is to perform a PSO, which usually achieves greater angular correction by removing a wedge of corticocancellous bone from the posterior aspect of the VB in combination with the removal of the articular processes, transverse processes, and pedicles. At the levels above and below the osteotomy, one must ensure that the bone and dorsal elements are adequately decompressed to prevent the neural elements from being compressed during the wedge closure process. After the posterior wedge has been closed, 2 nerve roots exit through the newly joined neural foramina (Fig. 3). By performing an asymmetrical removal of the posterior elements, correction of both sagit-
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![Image](image_url)

**Fig. 4.** Studies obtained in a 67-year-old man with AS who presented with low-back pain and difficulty ambulating. A and C: Note the significant sagittal imbalance preoperatively. B and D: The patient underwent a posterior approach with L-2 and L-4 PSOs with a T10–pelvic fixation and fusion for correction of the deformity.

tal and coronal deformities can be performed. By removing bone from the VB, the anterior column is not lengthened during the kyphosis correction, thus reducing the risk of damage to vascular structures caused by stretching the anterior column. This procedure is highly effective in restoring sagittal balance in patients with a fixed sagittal-plane deformity and has been commonly used in patients with AS. One can expect to gain 30–40° of correction at any given level when performing a PSO. It is possible to perform both thoracic and lumbar PSOs, and the decision of which level to target depends on each patient being treated. Thoracic PSOs are technically more demanding and are at a higher risk of producing neurological sequelae than lumbar PSOs. Because kyphosis correction is more easily tolerated at the level of the cauda equina, the correction achieved in a lumbar PSO is of greater magnitude than that of a thoracic PSO because surgeons can be more aggressive with their technique. In the setting of focal fixed-angle sagittal deformity, however, it may be necessary to perform a PSO at the respective level. In the absence of focal fixed-angle thoracolumbar kyphosis, lumbar PSOs are most commonly performed.

In 2005, Chang et al. compared SPO and PSO outcomes in AS patients with thoracolumbar kyphosis. For SPO and PSO procedures, similar corrections were achieved with an increase in lumbar lordosis by 37 and 36°, respectively. Operative times were 183 and 218 minutes and estimated mean blood losses were 1101 and 1915 ml. Sagittal imbalance was similar for both procedures (80 and 77 mm). Complications included delayed union in 3 patients and a broken rod at the osteotomy site in the SPO group. Six transient neurological deficits occurred overall. No mortality or major complications occurred. Five patients developed junctional kyphosis (2 undergoing opening and 3 undergoing closed wedge osteotomies), and all required repeat operation. Chang and colleagues concluded that they obtained satisfactory clinical outcomes in both groups but that PSO resulted in fewer instances of paralytic ileus and delayed union at the expense of longer operative time and more bleeding.

In 2002, Kim et al. reported outcomes in the treatment of 45 kyphotic patients with AS who had undergone PSO. They noted a 34° increase in lumbar lordosis and maintenance of thoracic kyphosis. Sagittal imbalance significantly improved from 94 to 8 mm, whereas sacral inclination increased from 8 to 24°. The CBVA was 32.0° before surgery and 0.9° after surgery. They reported a satisfactory clinical outcome in their patients and mentioned the following complications: paralytic ileus in 5 patients, monocular visual disturbance in 2, and neurological deficit in 5.

Spinal pseudarthrosis is another clinical entity commonly found in the workup of patients with AS and sagittal-plane deformity. Spinal pseudarthrosis may cause severe pain and neurological symptoms due to fibroosseous tissue proliferation around the site of the lesion. In 2007, Kim and associates reported results obtained in 12 AS patients with pseudarthrosis and sagittal-plane deformity. They performed a combination of SPOs and anterior interbody fusions at the site of pseudarthrosis. In a subset of patients, additional PSOs were performed to treat those with severe kyphosis. The authors reported an average correction of segmental kyphosis of 20.9° with SPO and 26.3° in those with lumbar PSO. The mean sagittal imbalance had improved 15.2 cm at the last follow-up. All 12 patients had improvement of pain and neurological dysfunction. There were 3 intraoperative dural tears, 2 postoperative radiculopathies, and 1 wound infection. Their study was indicative of how one can utilize both the SPO and PSO techniques to complement each other in the treatment of sagittal deformity in patients with AS.

**Correction of Flexion Deformity at Cervicothoracic Junction in AS**

The predominant indication for a cervical osteotomy is a significant flexion deformity in the neck that causes visual field limitation. At times, the flexion is so severe that the chin touches the chest, leading to difficulty eating and swallowing. Under these circumstances, the risks and benefits of cervical extension osteotomy surgeries are discussed with the patients.

McMaster has discussed his experience in treating AS patients with severe cervicothoracic flexion deformities. In brief, the operation was performed after induction of general anesthesia with the patient in the prone position and wearing a halo jacket. The C-6 and C-7 spinous processes
were excised, and a complete C-7 laminectomy was performed with partial C-6 and partial T-1 laminectomies. The C-8 nerve roots were exposed by removing the fused posterior facet joints. The C-7 and T-1 pedicles were then nibbled away to avoid pinching the C-8 nerve as the osteotomy was closed. To close the osteotomy, the hinges of the halo were unlocked and the head was extended while visualizing exposed dura amner. The ankylosed anterior column snapped, the head was placed in a neutral position, and the halo was locked.

McMaster 11 reported the treatment of 15 AS patients with the aforementioned technique. The preoperative mean cervical kyphosis in his series was 23°, and this was corrected to a mean of 31° of lordosis (correction of 54°). All the patients were able to see straight ahead. Complications included 1 patient with quadripareisis after 1 week, 2 patients with transient C-8 palsies, subluxation at the site of osteotomy in 4 patients, and episodes of pseudarthrosis requiring anterior fusion in 4 patients.11

Simmons et al.12 published a large retrospective review of their results in the treatment of AS patients with cervical extension osteotomies. They had 2 groups—114 patients in whom they used a conventional technique similar to that reported by McMaster, and 17 patients in whom they used a modified technique involving more extensive lateral bone removal that led to near-total bilateral C-7 pedicle removal. The average preoperative and postoperative angles were 56° and 4°, respectively, in the conventional group and 49° and 12°, respectively, in the modified technique group. They reported fewer neurological complications in the group associated with the modified technique and concluded that the increased lateral resection area reduces the risk of nerve root impingement and provides ample room for the spinal cord.

Conclusions

Ankylosing spondylitis represents one of the most challenging diseases for the spine surgeon. In patients with AS, it is important to assess the contribution of all levels of the spine to the overall flexed posture. The most common finding is a thoracolumbar deformity. If both thoracolumbar and cervicothoracic deformities are present, the spine surgeon should first consider correction of the thoracolumbar deformity, as this may be tolerated to a better extent and may have fewer complications. Both treatments nevertheless have been performed successfully by experienced surgeons and have risk–benefit ratios that make surgery a viable option when symptoms are severe.

References


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