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XLIF® for Anterior Column Realignment

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Note: The use of interbody fusion cages is not FDA-cleared for the treatment of thoracolumbar scoliosis, spondylolisthesis, multi-level (greater than two level) use, or use at levels other than L2 through S1. See cleared indications for use in the Appendix.

Sagittal imbalance is a complex deformity seen primarily in the adult population. The sagittal vertical axis (SVA), which is defined as the horizontal distance from a C7 plumbline (PL) to the posterior superior aspect of S1, is used to assess a patient's sagittal balance. Positive sagittal imbalance is significant when the SVA is greater than 4 cm.[1,2] This deformity can occur strictly in the sagittal plane or can occur in combination with coronal deformity. Positive sagittal balance can occur from many different etiologies, including degenerative disc disease, posttraumatic deformities, and iatrogenic deformity secondary to wide laminectomy or spinal arthrodesis with lumbar hypolordosis (iatrogenic flat back). The anterior trunk inclination that follows makes standing and walking inefficient as other compensatory mechanisms in the pelvis and lower extremities are used. This can often lead to increased effort and fatigue during standing and ambulation, pain in the back and lower extremities, resulting in severe disability.[2]

Sagittal balance has been shown in multiple studies to be the most important and reliable predictor of clinical health status, because patients with positive imbalance report worse outcome scores in relation to pain, function, and self-image. Correction of sagittal deformity has been shown to be the most important predictor for attaining a positive outcome after deformity surgery.[2] Measures of health status show significantly poorer outcomes as the sagittal vertical axis is increased.[1] Often, patients with positive sagittal imbalance present with a relative kyphosis of the lumbar spine. This has been shown to be associated with significantly more disability than patients with normal lumbar lordosis.

Historically, the correction of sagittal deformity is accomplished with open surgical exposures, often with the use of vertebral osteotomies for correction. The soft tissue support of the spine is completely disrupted, including the dorsal tension band, with injury to the paraspinal musculature and ligamentous structures. The morbidity and complications associated with these procedures is significant, which has encouraged an evolving interest in minimally invasive techniques.

This chapter introduces a novel technique for reconstruction of the anterior column using the extreme lateral interbody fusion (XLIF®, NuVasive®, Inc., San Diego, CA) approach with planned division of the anterior longitudinal ligament (ALL) and annulus. The advantages of this approach include a direct approach to the pathology with less tissue disruption, less blood loss, decreased pain, and decreased recovery time compared with traditional open osteotomies.

PATHOPHYSIOLOGY

Global spinal balance in the sagittal plane is achieved by the complex interaction between the spine and pelvis. When pathologic sagittal imbalance occurs, often there is a loss of lumbar lordosis (LL) that is compensated by retroversion of the pelvis and a decrease in sacral slope (SS) and increase in pelvic tilt (PT).[3,4] This often exacerbates loss of lordosis of the lumbar spine. This mechanism of compensation occurs in hopes of maintaining the SVA within normal ranges. However, once the pelvis maximally compensates and sagittal imbalance progresses, further distal articulations are recruited as compensatory mechanisms. Hip hyperextension occurs as well as knee flexion, which can lead to degenerative changes in those respective joints. The length of the disease course and associated degenerative changes will determine whether the deformity is rigid or flexible, and this will likely determine the operative plan.

TREATMENT OPTIONS

Initial Assessment

A thorough history should be obtained to assess the cause and duration of the patient's deformity, previous treatment, recent deformity progression, any recent increase in pain or disability, and the distribution of back and leg pain. Symptoms of radiculopathy and neurogenic claudication should be elucidated. The patient's comorbidities, nicotine use, and functional status are also obtained. Increased comorbidities and associated debilitation may cause patients to have an apparent physiologic age that exceeds their chronologic age, which may result in poor tolerance of the demands of an extensive reconstructive surgery. Physical examination should include assessment of spine extensor muscle groups and whether deformity is flexible or fixed with supine examination. Hip and knee examinations should be performed to identify flexion contractures, which may negatively affect surgical outcomes if left untreated or not considered in the preoperative plan. Treating physicians may want to consider nonoperative or appropriate limited operative treatment in this frail patient population. Conversely, if the patient's physiologic age appears to be equal to or less than the chronologic age, a discussion of more extensive reconstructive procedures may be appropriate.

Radiographic Evaluation

Optimal radiographic evaluation of adult spinal deformities includes standing 36-inch cassette anteroposterior and lateral radiographs of, at minimum, C7 to the pelvis and femoral heads. This evaluation allows assessment of the patient's coronal and sagittal balance, measurement of spinopelvic parameters, and simultaneous visualization of the primary and secondary scoliotic curves in the functional standing position. Newer techniques such as EOS-imaging system (EOS Imaging, Paris, France), if available, may even demonstrate the alignment of the lower extremities in relation to the spine and pelvis. A supine lateral bolster hyperextension radiograph delineates the flexibility of sagittal deformities and helps the treating physician to decide whether postural reduction of the deformity provides correction or if more extensive interbody reconstruction with or without ALL release can be performed or whether osteotomy procedures are needed.

As with other spinal disorders, advanced diagnostic imaging, including MRI and CT myelography, should be used to evaluate for neural element compression in patients with radicular or claudication symptoms. Although MRI is currently the standard diagnostic modality to assess neural compression, scoliotic vertebral rotation may confound MRI findings. In this setting, CT myelography may better delineate foraminal, apical, and lateral recess stenosis, although the benefits of myelography should be weighed against the invasive nature of this examination. MRI also allows assessment of intervertebral disc degeneration. Information gained from CT and MRI, in combination with radiographic evidence of disc degeneration, helps in the decision to include or exclude cephalad and caudad vertebral levels in the spinal arthrodesis. The presence of osteoporosis can accelerate the progression of deformity and may impact decision-making during surgical planning; therefore bone densitometry should be performed on patients with a reasonable risk of reduced bone density.

Nonoperative Management

The main goal of nonoperative management is to provide symptomatic relief, which can be through the use of medications such as NSAIDs and physical therapy aimed at strengthening core musculature and paraspinal musculature. Bracing can contribute to weakness and atrophy of musculature from prolonged use; therefore it does not play a significant role in the treatment of sagittal deformity.

Operative Management

Analysis of preoperative radiographs includes assessment of the C7 PL and its relationship to the sacral promontory. Spinopelvic parameters such as pelvic incidence, sacral slope, and pelvic tilt must be measured as well to be included in the operative plan for correction of sagittal deformity. The goals of correction should be SVA less than 5 cm, T1 tilt of 0 degrees, pelvic tilt less than 20 degrees, and lumbar lordosis within 9 degrees of pelvic incidence.[5]

When planning for deformity correction, one must take into account the overall health of the patient and clinical presentation and complaints. The mainstay of sagittal correction for larger deformities has been posterior-based osteotomies including the Ponte or Smith-Petersen osteotomy (SPO), pedicle subtraction osteotomy (PSO), or vertebral column resection (VCR). These osteotomies are powerful tools for correction of kyphotic deformities but have multiple drawbacks. They are technically demanding with greater operative times and higher blood loss that may compromise an already medically fragile patient.[6,7] Because of the significant morbidity imparted on these patients, the anterior column realignment (ACR) technique was developed in hopes of avoiding a three-column osteotomy in a patient with significant flexible sagittal deformity.

SURGICAL TECHNIQUE: ANTERIOR COLUMN REALIGNMENT

ACR is a modification of the XLIF technique previously described, with the use of specialized instruments and interbody cages for the treatment of sagittal deformity.

Standard lateral decubitus positioning with lateral fluoroscopic imaging is used to locate the disc space. Table flexion may be used to open the disc space, but overly aggressive flexion of the table may place excessive tension on the psoas muscle and lumbar plexus. A standard lateral retroperitoneal approach is made to the disc space ensuring neuromonitoring signals indicate a safe passage. The target of the first dilator and guide wire is the posterior third of the disc space to ensure a complete release of the contralateral annulus as well as facilitate the placement of the interbody cage.

After sequential dilation is completed and the three-blade retractor is inserted, the table mount is attached to the retractor. Next, a posterior shim is used to secure its position and prevent anterior migration of the retractor. The retractor is opened to visualize the anterior aspect of the annulus, which will appear to have a downward slope. Gentle anterior dissection is performed with the specialized curved Penfield dissectors. It is imperative to develop the plane directly anterior to the ALL and annulus in order to protect and retract the anterior vascular structures and prevent injury. Fluoroscopic imaging is used as well to ensure that the plane between the ALL and anterior structures is developed at least to the contralateral pedicle. Once a plane has been developed, the specialized anterior retractor is inserted using direct visualization and fluoroscopy and secured to the split-blade retractor as the fourth blade. The retractor width should be selected such that it does not fall within the disc space after the ALL is released.

A wide annulotomy is made, keeping the ALL intact. For a more controlled and thorough discectomy, it is important to have the restraint and control provided by the ALL. We have found an exposure of 24 mm or greater is necessary to accommodate a 22-mm wide cage. A thorough discectomy is performed with a wide ipsilateral and contralateral annular release. This may be performed per the surgeon's preference with a box-cutter and/or wide Cobb elevator. Successful isolation of the ALL may require careful attention during disc removal, particularly when working directly posterior to the ALL. Once the ALL is isolated and the anterior retractor is in the proper position, the ALL can be released sharply with the curved blade. A paddle distractor can be used to facilitate release of the ALL with tension and as confirmation of adequate release. If there is persistent tension during distraction, then the ALL or annulus must be reassessed and may require additional release.

Trialing is performed with standard implant sizes until a 12-mm trial can be inserted with minimal resistance. Next the ACR trials, which come in lordotic angles of 20 and 30 degrees, are inserted. After the appropriate sized implant is determined, a lateral image is used to confirm its position in the lateral plane. If acceptable, the hyperlordotic flanged cage (CoRoent® XL-H, NuVasive, Inc.) is placed through a posterior rail to guide the interbody cage into the proper location within the disc space and to prevent anterior migration. The positioning is confirmed in the coronal and sagittal planes under fluoroscopy. To prevent graft migration, a screw is placed through the flange into the bone adjacent to the endplate of the vertebral body. The cephalad location is preferred to avoid any prior pedicle screw instrumentation.

After adequate hemostasis is confirmed, wound closure is performed in a standard layered fashion for the lateral approach. The transversalis fascia is approximated with a heavier absorbable suture to minimize risk of hernia. A small round drain may be placed over the psoas muscle to decrease any hematoma formation within the muscle. If used, the drain is typically removed after the patient ambulates the following day.

TECHNICAL CONSIDERATIONS

To minimize complications associated with retraction such as psoas weakness, paresthesia, or neurologic injury, the retractor should initially be docked in the posterior spine and expanded to the minimum extent necessary for visualizing the disc space in both cephalad-caudad and anterior-posterior directions. Retractor expansion is limited to the margin of the disc space in the cephalad-caudad direction and exposure is mainly obtained in the anterior to posterior direction. It should be noted that the nearby neurologic structures during transpsoas exposure are peripheral nerves. As such, they should not be under static retraction or compression for prolonged periods. To reduce the duration of nerve retraction and compression, the initial discectomy is performed without visualizing the ALL, thereby keeping the exposure as small as possible; once complete discectomy has been performed, the ALL is then isolated. Intermittent release of the retractor will allow the nerves to recover if prolonged retraction is required.

Specific neuromonitoring techniques provide identification and direction of neurologic structures in the vicinity of the approach using continuously updated discrete-threshold evoked EMG (NeuroVision®, NuVasive, Inc.) to help guide the placement of the dilators and retractor. Free-running EMG and intermittent evoked EMG stimulation of the posterior blade may identify potential ischemia during prolonged retraction.

Because of the hyperlordotic nature of the implants and positioning of the vertebra, the neuroforaminal area may be reduced during ACR, particularly in patients with hypertrophic facets or those with pre-existing foraminal stenosis. In such cases, a posterior release or bilateral foraminotomy is typically used to alleviate symptomatic radiculopathy.

REPORTED RESULTS

Multiple studies have shown the effectiveness of minimally invasive techniques using the lateral approach for interbody fusion and posterior fixation for the treatment of adult deformity. Mundis et al[8] reviewed their experience with 16 patients with advanced scoliosis treated with the lateral approach for interbody fusion and a formal open posterior approach for supplemental fixation. They achieved an average of 45% correction with the interbody fusion alone and 70% after the second-stage posterior instrumentation and fusion. All patients had significant improvements in clinical parameters, including visual analog scale (VAS), Oswestry disability index (ODI), and SRS-22 scores. Sagittal parameters improved by restoring lordosis from 31 degrees preoperatively to 44 degrees postoperatively. Complications in this series included temporary paresthesias in 9 of 16 patients. Two patients (12.5%) had persistent symptoms at 2-year follow-up.

Anand et al[9,10] reported their results of minimally invasive deformity correction with the use of percutaneous pedicle screws posteriorly in 28 patients. Their reported blood loss for the anterior procedures was 241 mL; that for the posterior procedure was 231 mL. The mean preoperative Cobb angle was 22 degrees and corrected to 7 degrees postoperatively. They had significant improvement in VAS and ODI scores as well. Their overall major complication rate was 21% (six patients), with only two patients' complications directly related to the approach resulting in quadriceps weakness that resolved in 6 months.

To our knowledge, there is only one case series reporting the ACR technique. Akbarnia et al[11] reported their results on 17 patients with sagittal imbalance. Mean blood loss for the lateral approach with interbody fusions including ACR was 111 mL and 1,484 mL for the formal open posterior procedure. Fifteen patients (88%) had Smith-Petersen osteotomies at the level of the ACR. Two patients with severe sagittal imbalance had an additional pedicle subtraction osteotomy. Preoperative motion segment angle (MSA) averaged 9 degrees and improved to −19 degrees after ACR and to −26 degrees after posterior spinal fusion and instrumentation. Lumbar lordosis improved from −17 degrees preoperatively to −38 degrees after ACR and −44 degrees after posterior instrumentation.

Eight of seventeen patients in this series had complications. Four complications occurred following ACR. Three of these four complications occurred following ACR at L4-5, and one occurred following ACR at L1-2. Two patients experienced quadriceps paresis; one resolved by the 3-month follow-up and the other had persistent weakness in the quadriceps, tibialis anterior, and extensor hallucis longus, which finally improved to 4 out of 5 by the 12-month follow-up. One patient had acute L1 radiculopathy that was attributed to the level of the ACR at L1-2. This was treated with a Smith-Petersen osteotomy at L1-2 with bilateral decompression, and his symptoms resolved immediately after surgery. The fourth complication following ACR was a vascular injury following an anterior plate removal, which was repaired, and the patient experienced no specific problem during the course of her follow-up.

CASE EXAMPLES

Case 1

This 74-year-old woman presented with an L3 burst fracture. Prior surgical treatment included L2-4 posterior spinal fusion and instrumentation for treatment of severe central stenosis at L3 and multilevel bilateral foraminal stenosis at L3-4, L4-5, and L5-S1 after a motor vehicle accident that occurred 3 years prior. Despite doing fairly well for a short time after the initial surgery, she developed progressive sagittal imbalance and low back pain warranting surgical intervention. Pelvic parameters were defined and measured as follows: Pelvic tilt (PT) is the angle between the vertical reference line and the line drawn from the midpoint of the superior S1 endplate to the middle of the bifemoral head axis. Pelvic incidence (PI) is the angle between a line drawn from the midpoint of the superior S1 endplate to the middle of the bifemoral head axis and a line perpendicular to

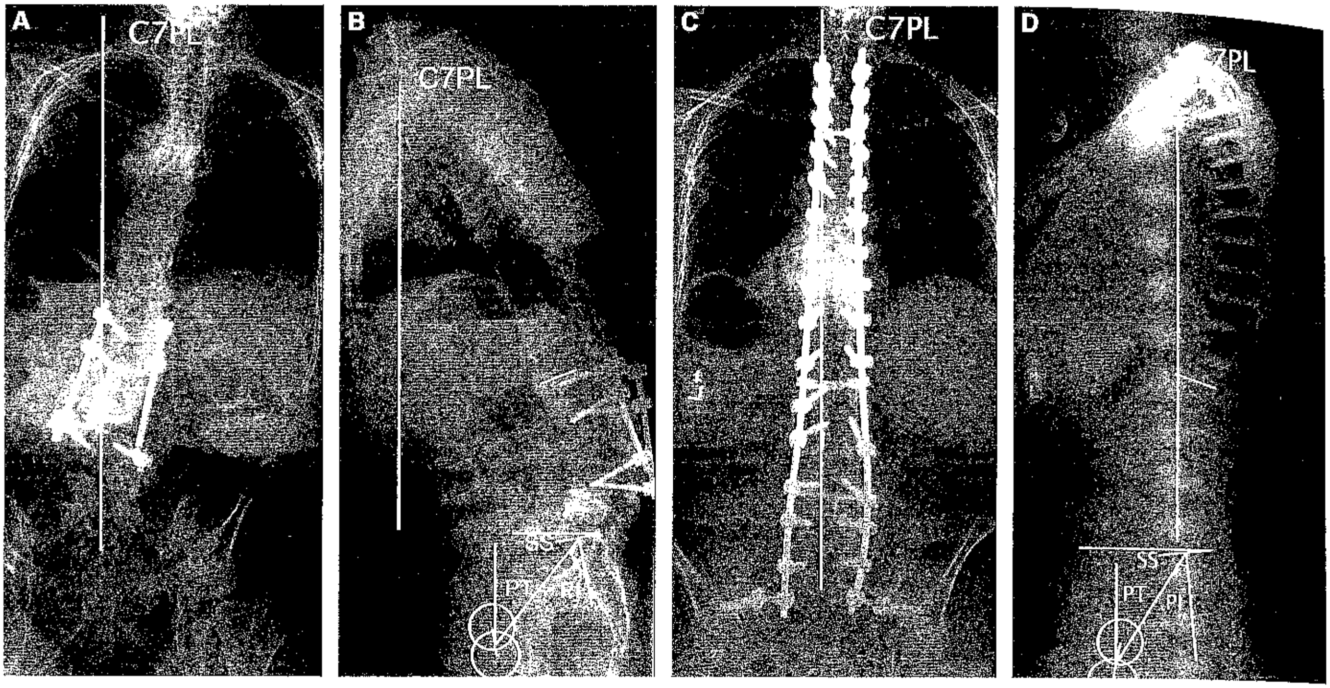

FIG. 30-1 **A,** Anteroposterior (AP) preoperative radiograph showing truncal shift to the right (C7 plumbline [PL], 100 mm). **B,** Lateral preoperative radiograph showing positive sagittal imbalance greater than 100 mm, lumbar kyphosis of 15 degrees, and abnormal pelvic parameters (pelvic incidence [PI], 46 degrees; pelvic tilt [PT], 37 degrees; lumbar lordosis [LL], +15 degrees). **C,** AP radiograph after anterior column realignment (ACR) and posterior spinal fusion showing restoration of coronal balance (C7 PL, 15 mm). **D,** Lateral radiograph after ACR and posterior spinal fusion showing restoration of sagittal balance (PI, 48 degrees; PT, 26 degrees; LL, −34 degrees).

the upper sacral endplate at its midpoint. Sacral slope (SS) is the angle between the horizontal line and the line tangential to the superior sacral endplate. Pelvic parameters were abnormal (PI, 46 degrees; PT, 37 degrees; LL, +15 degrees). AP and lateral radiographs showed failed back syndrome, obvious truncal shift to the right (C7 PL, 100 mm), severe positive sagittal imbalance (greater than 100 mm), and lumbar kyphosis of +19 degrees (Fig. 30-1, *A* and *B*). The patient underwent ACR with ALL release at L4-5 followed by posterior spinal fusion from T3 to pelvis on the same day. At the most recent follow-up visit the patient reported a pain level of 0. Recent AP and lateral radiographs (Fig. 30-1, *C* and *D*) show restoration of both coronal and sagittal balance (C7 PL, 15 mm; PI, 48 degrees; PT, 26 degrees; LL, −34 degrees).

Case 2

This 65-year-old man presented with progressive bilateral lower extremity pain and weakness, L5-S1 grade II degenerative spondylolisthesis, sagittal imbalance, and abnormal pelvic parameters (PI, 62 degrees; PT, 29 degrees; LL, −28 degrees) (Fig. 30-2, *A* and *B*). The patient underwent ACR with ALL release at L4-5 followed by posterior spinal fusion from L4-S1. The patient was hospitalized for 4 days after surgery. Postoperatively, the patient's reported pain level had decreased to 4 out of 10, compared with 8 out of 10 preoperatively. Most recent AP and lateral radiographs show normal coronal and sagittal balance and improved pelvic parameters (PI, 70 degrees; PT, 34 degrees; LL, −48 degrees) (Fig. 30-2, *C* and *D*).

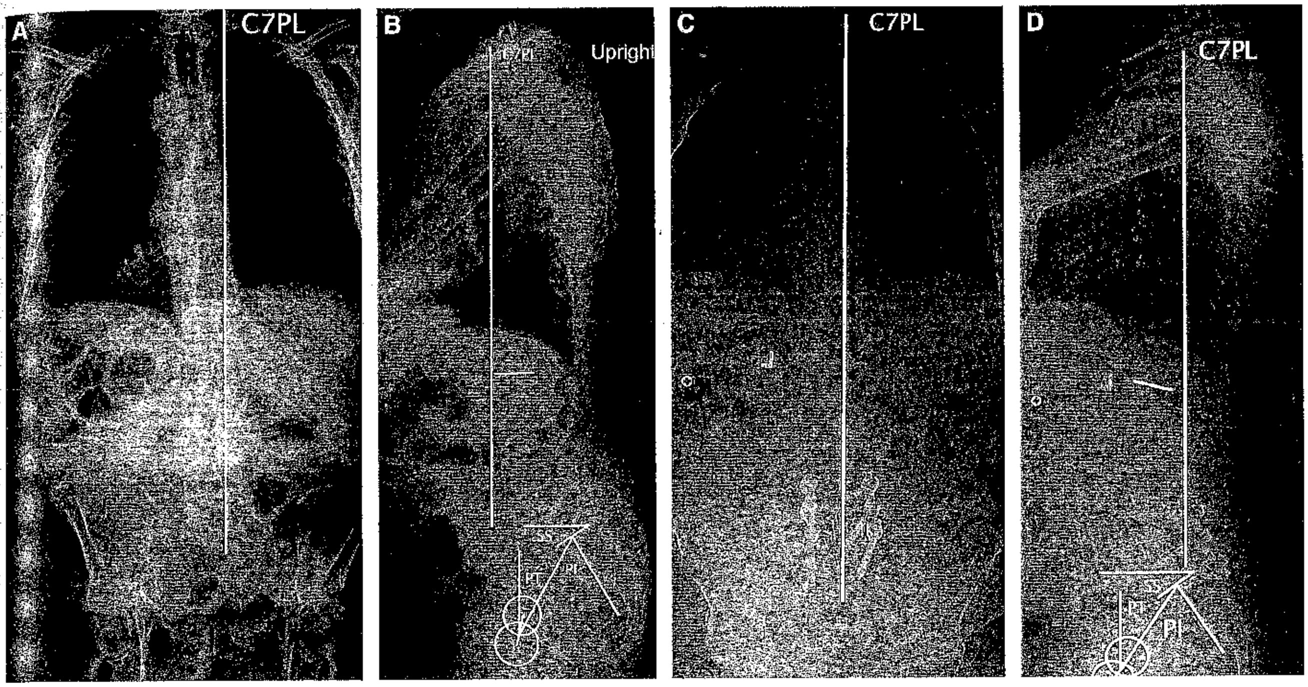

FIG. 30-2 **A,** Anteroposterior (AP) preoperative radiographs showing small coronal imbalance. **B,** Lateral preoperative radiograph showing grade II degenerative L5-S1 spondylolisthesis, sagittal imbalance, and abnormal pelvic parameters (pelvic incidence [PI], 62 degrees; pelvic tilt [PT], 29 degrees; lumbar lordosis [LL], −28 degrees). **C,** Postoperative AP radiographs after anterior column realignment (ACR) and posterior spinal fusion showing coronal alignment and balance is within normal limits. **D,** Postoperative lateral radiographs after ACR and posterior spinal fusion showing improved sagittal balance and pelvic parameters (PI, 70 degrees; PT, 34 degrees; LL, −48 degrees).

LIMITATIONS

The ACR technique is a promising tool for aiding in the correction of sagittal balance in the properly selected patient. The apex of the sagittal deformity must be flexible as demonstrated by a lateral bolster hyperextension radiograph. A deformity fixed anteriorly at the level of the disc space would require more extensive surgery and would be a relative contraindication. A posteriorly fixed deformity would require an osteotomy before ACR.

Because three of four major neurologic complications as described previously occurred at the L4-5 interspace, ACR at L4-5 should be performed cautiously. Anatomic studies of the lumbar plexus have suggested that the L4-5 disc space is the most precarious level for the lateral approach. The additional retraction and operative time required for the ACR technique may expose the lumbar plexus nerves to additional risk.

The ACR technique is also a good tool for the correction of relative kyphosis and normalizing the SVA. However, because ACR is performed at levels proximal to the L4-5 and L5-S1 interspace, it does not have a significant effect on pelvic tilt. Therefore addressing PT may require reconstruction anteriorly with interbody grafts if mild to moderate correction is desired, or with vertebral osteotomy for still more severe correction.

Vascular anatomy should be carefully studied on MRI. Abnormal vascular anatomy and aortic calcifications should serve as warning signs for potential complications with ACR. Furthermore, prior retroperitoneal infection, fibrosis, or prior anterior spinal surgery or retroperitoneal surgery near the level of interest may preclude patients from ACR.

CONCLUSION

In examples of flexible deformity, ACR provides a minimally invasive technique for the treatment of adult focal sagittal deformity. ACR can provide correction that is similar to three-column osteotomy focally, with reduction in morbidity to the patient. As with all deformity surgical techniques, it is associated with a risk of major complications including vascular and neurologic injury and should be performed by surgeons who have had the required training and experience in deformity surgery and the XLIF approach.

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