Spine Tips and Tricks: Anterior Column Realignment with Expandable Cage in Treating Sagittal Malalignment

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Introduction

Sagittal balance is a critical measure and reliable predicator of health status in patients with Adult Spine Deformity (ASD). Sagittal imbalance has shown to be associated with pain and worse clinical outcomes.[1-5] Nonsurgical management is often limited in alleviating symptoms in severe sagittal imbalance. Surgery is the standard of care with goal of improving lumbar lordosis (LL) and pelvic tilt (PT) to achieve achieving spinal fusion and restored sagittal balance. Traditional management has consisted of posterior-based surgical approaches with various osteotomy options including Smith-Petersen Osteotomy (SPO), Pedicle subtraction Osteotomy (PSO), and Vertebral Column Resection (VCR), with PSO being the most commonly used in treating fixed deformities.[6] These surgical techniques are successful in the treatment of patients with spinal deformity and restoring alignment goals; however, they carry significant morbidity including prolonged operative time, neurological complications, and risk of intraoperative bleeding.[7-10] Given the significant morbidity associated with such posterior shortening osteotomies, many surgeons prefer anterior-based interbody approaches to restoring sagittal alignment. With recent advancements in minimally invasive surgery (MIS) other options have emerged as promising alternatives in the management of adult spinal deformity including primary as well as revision spinal surgery.[11-14] Anterior column realignment (ACR) is a more recent MIS technique described for the correction of rigid kyphosis of the lumbar spine.[15] ACR is an anterior column lengthening procedure that utilizes the minimally invasive lateral lumbar interbody fusion (LLIF) approach to perform a complete discectomy with deliberate release of the anterior longitudinal ligament (ALL). ACR has been shown to be equally effective and safer alternative to the traditional three column osteotomy.[16] Selecting the appropriate surgical technique is crucial to success.

Indications

Anterior column realignment (ACR) is an emerging minimally invasive (MIS) treatment for sagittal deformity. Surgical indications include progressive focal sagittal deformity and instability, declining neurological status, and declining quality of life secondary to sagittal imbalance. Absolute contraindications include a fused disc space at the affected level, as well as relative contraindications that are shared with any lateral retroperitoneal approach surgery including anatomic access concerns in the lumbosacral spine, retroperitoneal adhesions, and vascular concerns.

Preoperative Planning

Thorough preoperative planning is essential for a safe and effective surgery. Preoperative imaging provides understanding of the spinal deformity. Standing alignment radiographs allow measurement of sagittal parameters and identification of dynamic instability. Advanced imaging such as CT scan allow assessment of bony fusion. MRI identifies any underlying associated neurologic compression as well as anatomical constraints such as vascular anomalies and lumbosacral plexus variants within the psoas musculature. These considerations also help determine the optimal side for approach, with the safest and most effective trajectory. The surgeon can also assess the relation of the great vessels relative to the anterior spine and explore for a safe plane for dissection of the ALL.

Surgical Technique

The approach for ACR as described by Akbarnia et al. in 2014 is through the lateral trans-psoas corridor to access the lateral spine. Patient should be positioned for a standard LLIF approach in the lateral decubitus position. Lateral flank incision at the level of intervertebral disc of interest is made, followed by blunt dissection through abdominal wall musculature and into the retroperitoneal space. This generally allows access to the levels between L1 and L5. Directional EMG is utilized to guide appropriate psoas dissection to allow safe access to the lateral spine while avoiding injury to the lumbar plexus. Once at the lateral spine, careful anterior dissection is performed to create a plane between the ALL and anterior vascular structures, however, the ALL is kept intact until full discectomy is performed. A retractor is placed in position anterior to the ALL. Then ipsilateral and contralateral annulectomies are performed and complete discectomy is performed. Vertebral body endplates are prepared with cartilaginous removal in anticipation of fusion. Once the discectomy is completed, the ALL is identified and the vascular structures anterior to the ALL are protected, the surgeon can then proceed with direct ALL resection with a scalpel. After the release is complete, an appropriately sized expandable mechanical interbody cage is inserted into the disc space under fluoroscopic guidance. Traditional hyperlordotic 30-degree cages, while providing significant sagittal plane correction, can be difficult to restrict posteriorly within the interbody space without the constraint of ALL intact. Expandable implants in this scenario provide the benefit of being inserted at 10 degrees of lordosis, facilitating safe placement within the interbody space. Another theoretical benefit is decreased insertional stress on the vertebral endplates with less risk of subsidence into bone. Integrated screw fixation is then inserted into the cephalad vertebral body to avoid anterior migration of the cage and a second screw is often fixed into the caudal vertebral body for additional support. The cage, once fixated, can then be expanded to higher degrees of lordosis in-vivo without concern for further anterior migration while still providing significant anterior column lengthening and lordotic correction. Bone graft material can then be inserted to allow for interbody fusion. Posterior instrumented fusion is then performed at least two levels cephalad and caudal to the ACR level for further stability. Posterior column osteotomy (PCO) can be performed concurrently to enhance power of correction if needed.

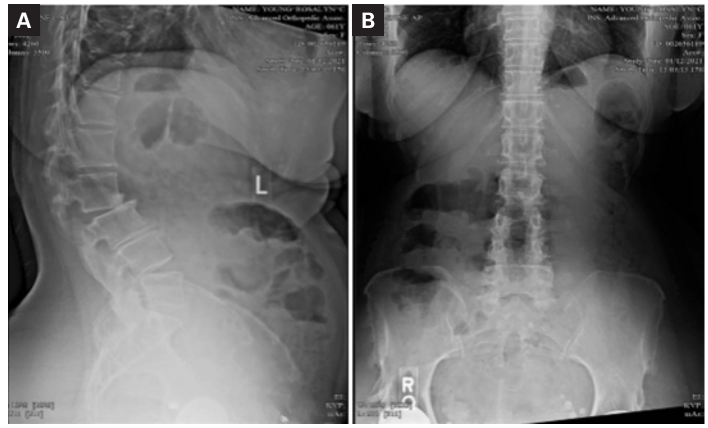

Figure 1. Pre-operative imaging. **(A, B)** AP and lateral X-rays, respectively, demonstrating 30 degrees segmental kyphosis and progressive instability at L2-L3. Pelvic incidence, 35 degrees. Lumbar lordosis, 8 degrees.

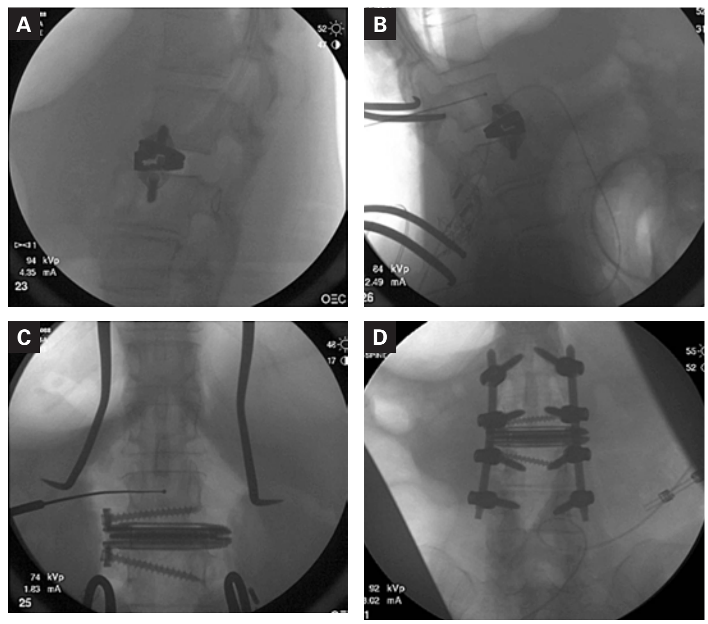

Figure 2. Intra-operative imaging. **(A)** Lateral intraoperative X-ray demonstrating placement of the expandable cage at the L2-L3 level prior to SPO, and **(B)** after the SPO. **(C)** AP intraoperative image prior to instrumented fusion, and **(D)** final AP status post final instrumentation.

Example Case

Patient X, 62-year-old female with past medical history significant for HTN and alopecia. Presented to clinic for back pain, progressive lower extremity (worse on the left), and new onset urinary urgency, in the setting for having prior L2-L5 laminectomy approximately 2 years prior at outside institution. Prior to onset of urinary urgency, she had completed interval non-operative treatment (physical therapy, multiple epidural steroid injections) with no relief of symptoms. On examination, her motor strength was 5/5 throughout bilateral lower extremities, except for 4/5 bilateral hip flexion. Sensation was intact bilaterally. X-rays showed progressive post-laminectomy kyphosis with segmental progressive instability at L2-L3 (Figure 1).

Given the progressive deformity with neurologic dysfunction the patient was an appropriate candidate for surgical intervention. She underwent pre-operative testing and was cleared for surgery.

Patient underwent ACR with L2-3 LLIF with expandable cage and L1-L4 PSF (Figure 2). The lateral portion of the case was performed first starting with the discectomy, followed by release of the ALL. The expandable cage was packed with allograft bone graft and patient's left iliac crest bone marrow aspirate. The lateral plate was integrated with the cage and screws were placed through the bodies of L2 and L3 to help avoid cage migration. The cage was then expanded from 10 to 30 degrees. Finally, in the posterior portion of the case, patient had a Smith Petersen Osteotomy at the level of L2-L3 for additional sagittal correction and L1-L4 instrumented fusion.

Patient's pain was improved on post-operative day 1, and patient was ambulating with physical therapy. Urinary urgency, in addition to the pain, were improved post-operatively. She received 2 units of pRBC for hemoglobin of 6.7 which corrected appropriately, most likely secondary to dilutional rather than significant blood loss (given that her estimated blood loss during surgery was 200cc). Patient was discharged home on post-operative day 5, her delay in discharge was mainly due to high posterior drain output given the revision

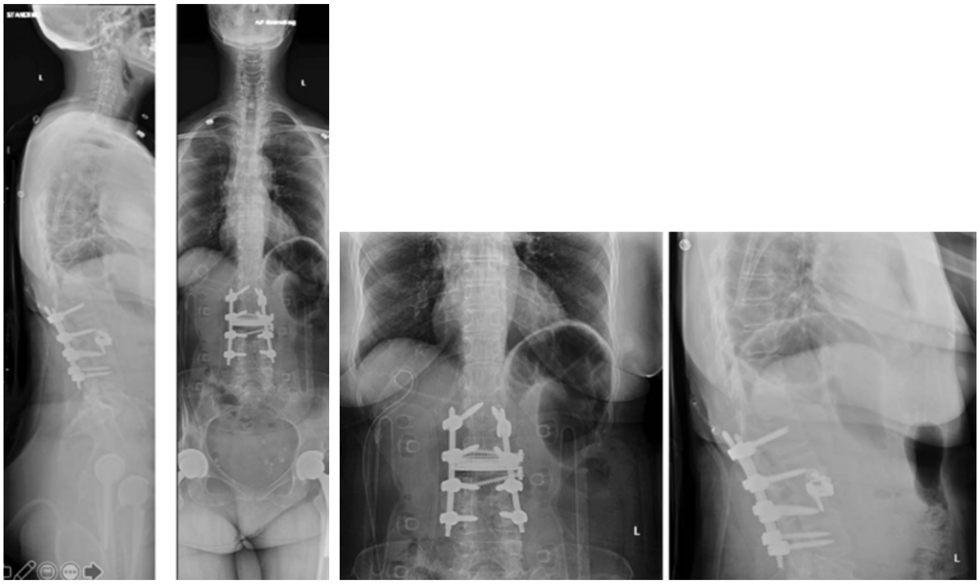

Figure 3. Post-operative imaging demonstrating restoration of lumbar lordosis. L2-3 segmental lordosis, 4 degrees. Lumbar lordosis 42 degrees.

posterior exposure. Post-operative imaging shows restored lumbar lordosis, with the expandable cage positioned properly (Figure 3).

Discussion:

Post-laminectomy kyphosis is more common in the pediatric population than in adults with incidence as high as 26% in children who underwent laminectomy. It more commonly occurs in the cervical spine than the thoracolumbar spine. Higher occurrences have been reported in children undergoing laminectomies for cord tumors, with incidence reported as high as 50% in this population. It is postulated that laminectomy in the skeletally immature spine leads to decreased cartilage growth and anterior wedging of vertebral bodies. While in the adult population, post-laminectomy kyphosis has been shown to be influenced by multiple factors including pre-existing sagittal deformity, more significant facet resection, and muscular insufficiency post laminectomy. Nonetheless, post-laminectomy lumbar kyphosis in adults is not robustly described in the literature. Here, we presented an interesting case with an adult patient with post-laminectomy kyphosis in the lumbar spine.

Traditional 3-column osteotomies (3CO) provide powerful alignment correction of sagittal deformities but come at the expense of increased morbidity. Bianco et al. reported overall rate of major complications (including intraoperative and postoperative complications) of 42% in a retrospective study of 423 patients who underwent 3CO. Smith et al. reported a higher percentage of 78% of patients with at least one complication (including major and minor complications) in a retrospective study of 82 patients with at least 2 year follow up. Most common complications are excessive blood loss, neurological deficits and instrumentation related complications. Neurological deficits were reported as either radiculopathy or motor deficits. Implant-related complications were most commonly rod-breakage. Major blood loss (defined as loss of >4L) has been described in the literature to correlate with increased risk of infections and overall medical complications. Bianco et al. identified major blood loss as a direct risk factor for developing complications in patients undergoing 3CO with patients losing 55% of their blood volume intraoperatively. Such complications include dural tears, deep wound infection, and cardiopulmonary complications (e.g. pulmonary embolism).

The advent of expandable interbody cages over the last several years have presented the theoretical advantages of decreased insertional endplate stresses as well as the ability to "dial in" variable degrees of lordosis.[21] Though first developed for transforaminal interbody fusion (TLIF) devices; expandable technology has more recently been applied to LLIF devices. The larger LLIF cages in general allow for more surface area for fusion as well as the ability to span the more robust apophyseal ring of the vertebrae. The novel usage of expandable hyperlordotic (lordosis greater than 20 degrees) LLIF devices in the setting of anterior column realignment (ACR) is not well explored and warrants further long-term study.

ACR, in general, offers an effective less invasive alternative for sagittal imbalance correction without may of the associated complications of traditional 3CO. Notably, ACR has been shown to be associated with significantly less blood loss compared to the 3CO b obviating the need for extensive bony resection.[18, 19] ACR does present its own approach-specific risk profile. Neurological deficits related to the lumbar plexus have been reported due to the transpsoas approach, however, these deficits were invariably transient.[20] Further larger scale analysis of outcomes and complication's related to ACR is warranted. Thus far, ACR has demonstrated to be an effective procedure for restoring sagittal alignment in appropriately indicated patients with lower rates of complications when compared to traditional 3CO.

References:

1. Glassman SD, Berven S, Bridwell K, *et al*. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine* 2005;30:682–8. 15.

2. Lagrone MO, Bradford DS, Moe JH, *et al*. Treatment of symptomatic flatback after spinal fusion. *J Bone Joint Surg Am* 1988;70:569–80. 16.

3. Booth KC, Bridwell KH, Lenke LG, *et al.* Complications and predictive factors for the successful treatment of flat-back deformity (fixed sagittal imbalance) *Spine* 1999;15:24:1712–20.

4. Glassman SD, Bridwell K, Dimar JR, *et al.* The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976)* 2005 Sep 15; 30(18):2024-9.

5. Harroud A, Labelle H, Joncas J, *et a*.. Global sagittal alignment and health-related quality of life in lumbosacral spondylolisthesis. *Eur Spine J.* 2013 Apr; 22(4):849-56.

6. Pateder DB, Kebaish KM, Cascio BM, *et al*. Posterior only versus combined anterior and posterior approaches to lumbar scoliosis in adults: A radiographic analysis. *Spine* 2007; 32: 1551-1554.

7. Dorward IG and Lenke LG. Osteotomies in the posterior-only treatment of complex adult spinal deformity: a comparative review. *Neurosurg Focus* 2010;28:E4. 4.

8. Hyun SJ and Rhim SC. Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients: a longterm follow-up data. *J Korean Neurosurg Soc.* 2010;47:95–101. 5.

9. Gill JB, Levin A, Burd T. Corrective osteotomies in spine surgery. *J Bone Joint Surg Am.* 2008;90:2509–2520. 6.

10. Bridwell KH, Lewis SJ, Edwards C. Complications and outcomes of pedicle subtraction osteotomies for fixed sagittal imbalance. Spine. 2003;28:2093–2101

11. Anand N, Kong C, Fessler RG. A Staged Protocol for Circumferential Minimally Invasive Surgical Correction of Adult Spinal Deformity**.** *Neurosurgery* 2017;81:733-9. 10.1093/neuros/nyx353.

12. Choy W, Miller CA, Chan AK, *et al.* Evolution of the Minimally Invasive Spinal Deformity Surgery Algorithm: An Evidence-Based Approach to Surgical Strategies for Deformity Correction. *Neurosurg Clin N Am* 2018;29:399-406. 10.1016/j.nec.2018.03.007

13. Mummaneni PV, Shaffrey CI, Lenke LG, *et al.* The minimally invasive spinal deformity surgery algorithm: a reproducible rational framework for decision making in minimally invasive spinal deformity surgery. *Neurosurg Focus* 2014;36:E6. 10.3171/2014.3.FOCUS1413.

14. Lee YC and Lee R. Minimal invasive surgical algorithm for revision lumbar spinal surgery. *J Spine Surg.* 2019;5(4):413-424. doi:10.21037/jss.2019.09.08

15. Akbarnia BA, Mundis GM Jr, Moazzaz P, *et al.* Anterior column realignment (ACR) for focal kyphotic spinal deformity using a lateral transpsoas approach and ALL release. *J Spinal Disord Tech.* 2014 Feb;27(1):29-39. doi: 10.1097/BSD.0b013e318287bdc1.

16. Saigal R, Mundis GM Jr, Eastlack R, *et al.* Anterior Column Realignment (ACR) in Adult Sagittal Deformity Correction: Technique and Review of the Literature. *Spine (Phila Pa 1976)* 2016 Apr;41 Suppl 8:S66-73. doi: 10.1097/BRS.0000000000001483.

17. Schwab F, Dubey A, Gamez L, *et al.* Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. *Spine (Phila Pa 1976).* 2005 May 1; 30(9):1082-5.

18. Mundis GM Jr, Turner JD, Kabirian N, *et al*. International Spine Study Group. Anterior column realignment has similar results to pedicle subtraction osteotomy in treating adults with sagittal plane deformity. *World Neurosurg.* 2017;105:249-256.

19. Hassanzadeh H, Jain A, El Dafrawy MH, *et al.* Three-column osteotomies in the treatment of spinal deformity in adult patients 60 years old and older: outcome and complications. *Spine (Phila Pa 1976)* 2013;38:726-731.

20. Cummock MD, Vanni S, Levi AD, *et al.* An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody. *Journal of Neurosurgery: Spine SPI* 2011, 15(1), 11-18.

21. Boktor, J. G., Pockett, R. D., & Verghese, N. The expandable transforaminal lumbar interbody fusion—Two years follow-up. *Journal of Craniovertebral Junction & Spine 2018*, 9(1), 50–55..