Strategies to Avoid Distal Junctional Pathology

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KEYWORDS

• Distal junctional kyphosis • Distal junctional failure • Lumbosacral junctional pathology

KEY POINTS

- Distal junctional pathology remains an unsolved problem in spine surgery and a less well-studied issue than proximal junctional pathology
- Depending on the etiology of the spine deformity there are techniques to reduce distal junctional pathology with the basic strategy of appropriate lowest instrumented vertebra (LIV) selection and fixation methods.
- When distal junctional pathology requiring intervention occurs, the basic principles require strengthening the area of failure and usually extending the construct to a more caudal LIV.

INTRODUCTION AND HISTORY, DEFINITIONS, BACKGROUND

The advent of modern segmental spinal instrumentation has allowed for greater control of spinal deformity correction over previous techniques such as Harrington rods. However, postoperative decompensation was soon recognized as an entity and the sagittal plane subsequently gained significant attention in the literature. The first report of kyphosis at the distal junction of the instrumented and non-instrumented spine following segmental spinal instrumentation came when Richards and colleagues[1] demonstrated that in their series of 53 patients with adolescent idiopathic scoliosis (AIS) treated with Cotrel-Dubousset instrumentation, one-third developed postoperative radiographic junctional kyphosis.

The definition of distal junctional kyphosis (DJK) as the development of kyphotic angulation $\geq 10^{\circ}$ at the distal segment of a fusion construct was first introduced by Lowe and colleagues[2] in 2006 in their retrospective series of 375 patients with AIS. They reported the postoperative incidence of DJK in this population to be 7.1% for those undergoing anterior fusion and 14.6% in those undergoing posterior fusion.[2]

While DJK is a radiographic definition, distal junctional failure (DJF) is understood to be clinical or radiographic signs of failure at the caudal end of the construct for a variety of reasons (**Fig. 1**). These include but are not limited to symptomatic DJK, construct failure including rod fracture and/or screw plowing/pull out, pseudarthrosis, fracture, and adjacent segment disease.

Unlike the proximal junction, pathology at the distal junction has been less studied overall. Perhaps due to its lower incidence. It remains an unsolved problem in multiple surgical settings such as AIS, Scheuermann's Kyphosis, and adult spinal deformity (ASD) surgery.

NATURE OF THE PROBLEM/DIAGNOSIS

Diagnosis

Distal junctional pathology (DJP) is typically diagnosed by radiographic imaging postoperatively with or without patient symptoms. Patients may be asymptomatic with only a radiographic diagnosis of DJK. Others may report more acute

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Fig. 1. The radiograph on the left illustrates radiographic DJK. The radiograph on the right demonstrates DJF in a short thoracic fusion with screw pullout at the LIV.

events and report a sound or sensation related to construct failure such as rod fracture or screw failure. It may present more insidiously with continued pain postoperatively and observed pseudarthrosis, or adjacent segment disease diagnosed on advanced imaging.

The obvious goal is to eliminate or decrease DJP as a reduction in postoperative complications of spine surgery is beneficial for outcomes. While DJK can be observed radiographically without deterioration of clinical outcomes it could be considered a first step toward a pathway leading toward DJF which can be clinically problematic.

The burden of disease for DJP can be variable depending on the clinical setting. In ASD, DJF has been reported with an incidence between 1.8% and 15.6%.[3] DJP has been reported as high as 15%, 50%, and 24% in AIS,[2] Scheuermann's Kyphosis,[4] and cervical spine surgery[5] respectively with modern instrumentation.

While the problem has been long identified, it remains unsolved. However, risk factors have been elucidated in the literature that fall into one of two categories, technical and patient specific.

Technical risk factors that have been addressed include the selection of the lowest instrumented vertebra and methods of fixation at the distal end of the construct. With the discovery of technical risk factors, DJP avoidant strategies have been developed although are still not entirely agreed upon by the surgical community. Patient-specific risk factors described broadly fall under preoperative radiographic alignment parameters, anatomy, and other medical conditions.

Current evidence

The lowest instrumented vertebra Much of the literature investigating DJP has been focused on the lowest instrumented vertebra (LIV) because of surgeons' desire to obtain the most rigid, stable construct and limit the risk of distal failure while maintaining as much flexibility in the spine as possible.

Adult spinal deformity Many ASD patients with posterior fusions require fusion to the sacrum or ilium in the index procedure due to apriori distal lumbar degeneration which will ultimately serve to protect the construct against DJP. Yasuda and colleagues found that lumbosacral failure decreased when using iliac screws in a study of 25 patients.[6] The authors advocated for spinopelvic fixation using an iliac screw as the lower fusion level in contrast to L5 or S1 due to a 76% incidence of complications in the cohort fused to L5 or S1 versus a 12.0% rate in the iliac fusion group. In a recent meta-analysis by Cavagnaro and colleagues, it was similarly reported that pelvic fixation had a protective effect against junctional failure as measured by pseudarthrosis at the lumbosacral junction.[7] The enhanced stiffness and strength of the construct with pelvic fixation was likely the reason behind this clinical finding and is supported by biomechanical reports that iliac fixation produces higher load to failure than only sacral fixation regardless of configuration.[8]

Similar recommendations for pelvic fixation were made by Ushio and colleagues based on patient-specific pre-operative radiographic parameters. Ushio and colleagues reported a cohort of 52 patients undergoing fusion to L5 with LIV failure in 20 patients and revision surgery in 6 patients. The authors noted a significantly higher pelvic incidence (PI) in the failure group.[9] Consequently, sacro-pelvic fixation should be considered in patients with a high preoperative PI and long fusion stopping at L5 should be avoided in this patient group.[10]

In addition to level selection for primary constructs, when using accessory rods the LIV should be carefully considered. Lee and colleagues found that when utilizing sacro-pelvic fixation the level of the accessory rods at S2/ilium was protective in a study of 253 ASD patients. The authors reported that pelvic fixation failure was significantly reduced when the accessory rod LIV was S2/ilium versus S1.[11]

While many surgeons advocate for index fusion to the pelvis there are select patients that can have the fusion short of the pelvis where the correct level is widely debated. In particular, it has yet to be determined if patients with a healthy L5-S1 segment should have fusion stopped at L5 or extend to the sacrum. Results reported have been equivocal and each level has been shown to come with its own corresponding complications such as higher pseudarthrosis rate in fusions ending in the sacrum and increased adjacent segment disease and loss of sagittal balance in fusions stopping at L5.[12,13]

While fusion to the sacrum/pelvis seems a reliable standard for long constructs it should be noted when selecting to fuse into the sacrum or ilium there is an increased risk for proximal junctional kyphosis.[10] Additionally exposing the sacrum adds to the length and morbidity of surgery and has a higher pseudarthrosis rate. Fusing L5-S1 may also alter the mechanics of patient gait. As such, the decision to fuse to the sacrum must be balanced by the deformity correction required, length of the fusion, status of the L5-S1 disc space, and risk of pseudarthrosis and revision surgery.

Scheuermann's kyphosis In the setting of thoracic hyperkyphosis or Scheuermann kyphosis, historically it had been advocated all patients should have constructs from T3-L2[14] or that the distal level should include the end vertebra and first lordotic disc (FLD).[15,16] However, FLD selection can be challenging as the true FLD can be difficult to determine as patients often have compensatory hyperlordosis below the hyperkyphotic segment leading to inappropriately short fusions. Due to this challenge and the continued rate of DJK, the stable sagittal vertebra (SSV) concept was proposed to select the LIV (**Fig. 2**). The SSV is defined as the most proximal vertebra touched by a vertical line from the posterior superior corner of the sacrum on lateral imaging. Cho and colleagues reported a significant decrease in DJK (4% vs 71%) when fusion extended to a more distal SSV than the first lordotic vertebra (FLV).[17] In another direct comparison of FLV to SSV methodology using all posterior all pedicle screw instrumentation, Kim and colleagues found a lower rate of revision surgery explicitly for DJK (5.0% vs 36.3%) when the SSV was selected.[18] Luzzi and colleagues further investigated appropriate LIV selection/fusion and found fusion to the second vertebrae below the first lordotic disc decreased the development of DJK.[19]

While evidence supports fusion to or beyond the SSV, other authors suggest longer fusion than the FLV is unnecessary because they found similar rates of DJK and revision surgery in patients fused to the SSV and FLV. Xu and colleagues stratified Scheuermann's Kyphosis into different curve patterns based on the kyphotic apex, as thoracic kyphosis versus thoracolumbar kyphosis and found that shorter fusions stopping at the FLV, which coincided with the vertebra above SSV, achieved comparable outcomes to SSV fusion and did not increase DJK incidence in either curve patterns.[20] Authors contend fusing to the FLV preserves levels and aids in avoiding adjacent segment degenerative disc disease in the lumbar spine, which may be caused by posterior fusions to L4 and L5 (**Fig. 3**).[21] However, this adjacent segment degeneration in the lumbar spine may not be clinically relevant as suggested by MRI and patient-reported outcomes.[22]

Adolescent idiopathic scoliosis Optimal level selection is essential in AIS to prevent

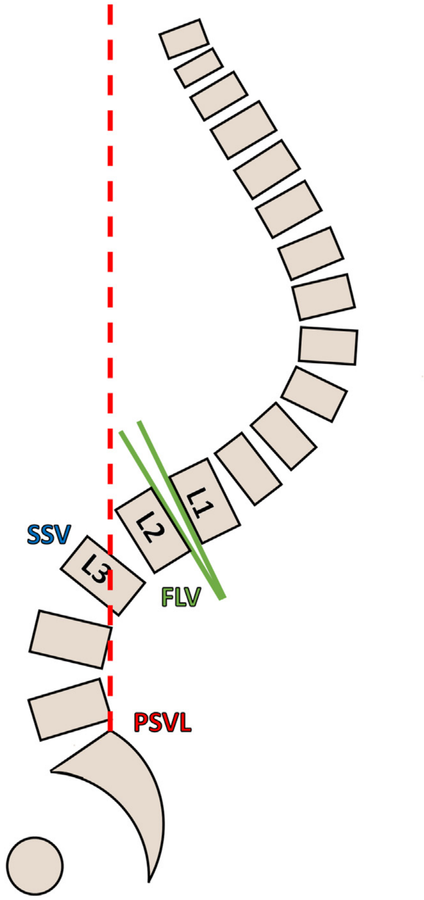

Fig. 2. Graphical representation of the lateral spine in Scheuermann's kyphosis. The posterior sacral vertical line (PSVL) is represented by the dashed red line. The most proximal vertebra touched by the PSVL is the SSV. The FLD is represented by the green lines and is the distal first lordotic disc space. The FLV is the first vertebra immediately caudal to the FLD. In this example, L2 is the FLV and L3 is the SSV.

decompensation and avoid the adding-on phenomenon and DJK. Similar to other deformity etiologies, preventing complications by utilizing longer fusions have to be weighed against the loss of mobile segments.[23,24] Various methods have been proposed for level selection in AIS with a historical focus on the coronal plane and the prevention of the adding on. Goldstein described fusing 1 to 3 levels below the primary curve in 1964.[25] Harrington introduced the concept of the stable zone to select the LIV[26] which was further expounded on by King and colleagues into the concept of the stable vertebra, the vertebra most bisected by the central stable vertical line.[27] Suk and colleagues[28] demonstrated the relationship between the end vertebra and the neutral vertebra in main thoracic curves, showing satisfactory outcomes with fusion to the neutral vertebra when the preoperative neutral vertebra was the same level as or one level distal to the end vertebra. When the neutral vertebra was two or more levels distal to the end vertebra, fusion to one level shorter than the neutral vertebra resulted in satisfactory outcomes.[28] The last touched vertebra (LTV), initially promoted by Lenke and colleagues, defined as the most cephalad thoracolumbar/lumbar vertebra "touched" by the CSVL has been proposed as the LIV with good outcomes from multiple authors.[29,30] Cho and colleagues[31] introduced the concept of the last substantially touched vertebra, defined as the most cephalad lumbar vertebra in which the CSVL intersects the pedicle or is medial to it. Multiple authors have demonstrated a higher risk of adding on when the LTV is selected as the LIV versus the LSTV.[32,33]

Fischer and colleagues[34] synthesized the concepts of the stable vertebra, neutral vertebra, and LTV in a large retrospective study of 544 patients with thoracic AIS and found higher rates of adding on or DJK in patients with LIV proximal to the LTV and three or more vertebra proximal to the neutral vertebra as well as in those with open triradiate cartilage. In order to prevent adding on or DJK they recommended the selection of an LIV that is touched by the CSVL and within 2 vertebra proximal to the neutral vertebra in patients following closure of the triradiate cartilage.[34]

More recent literature has begun to focus on the sagittal plane in level selection in AIS, especially as awareness has grown for its implications in the development of DJK. As previously discussed, Lowe and colleagues[2] found that in their series of 375 patients with AIS, DJK was twice as common (14.6% compared to 7.1%) in patients undergoing posterior fusion as opposed to anterior fusion. Development of DJK in the posterior group was associated with a lowest instrumented vertebra (LIV) at the end vertebra rather than 1 or 2 levels beyond. They also demonstrated that failure to restore or maintain normal sagittal alignment in the thoracic and thoracolumbar region were risk factors for the development of DJK. They hypothesized that this was less of a problem in the anterior group through the use of interbody structural support.

Yang and colleagues[35] first applied the concept of the SSV to AIS in 2018 to identify the effectiveness of using the SSV for selecting the LIV to prevent DJK in selective thoracic fusions. In their series of 113 patients, 17% of those with an LIV above the SSV developed DJK whereas 0% of those with an LIV at or distal to the SSV developed DJK. Segal and colleagues[36] demonstrated that at 5 years postoperatively, 15.6% of patients with LIV

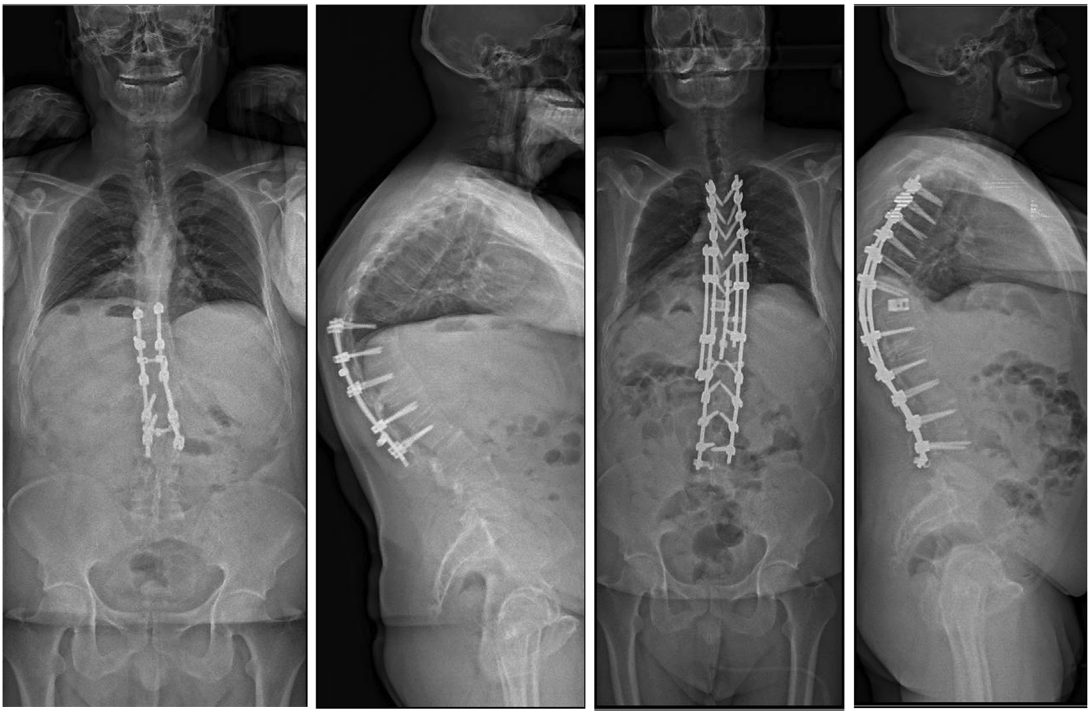

Fig. 3. Example Scheuermann's kyphosis pre- and post-operatively. The patient underwent the removal of hardware from T9-L2 followed by PSF T3-L4. Anterior fusion was performed at T8-T11. Posterior column osteotomies were performed at T6-T8 and L2-L3. Additional VCR performed at T9-T10.

above the SSV developed DJK versus 2.2% in those with fusions below the LIV. In a large retrospective study of 856 patients, Marciano and colleagues[37] found that 13.3% of patients had an LTV and an SSV that were not at the same level. Of these patients with a discordant LTV and SSV, 7.7% of those with fusions including the SSV developed DJK whereas 45.5% of patients with fusions short of the SSV developed DJK. Patients with shorter fusions demonstrated improvements in pain scores measured by SRS-22, but only when they did not develop DJK.[37] Segal and colleagues[38] expanded on these findings with a multicenter study demonstrating that 18.5% of patients with an SSV below the LTV who were fused to the LTV developed DJK while no patients with an SSV above the LTV developed DJK, regardless of fusion to the LTV, SSV, or between. Notably, they found that 95% of DJK occurred in patients with fusions ending at T11, T12, and more rarely L1.[38] In their study, preoperative thoracolumbar hyperkyphosis was identified as a risk factor for the development of DJK, as was a postoperative distal junctional angle greater than 5°, with the latter resulting in a greater than 16 times risk of DJK.[38]

Methods of fixation in the distal segment After LIV selection, optimal methods of fixation should be considered.

There can be a great deal of variety in pelvic fixation constructs including screw size, number of screws, number of rods, and level of fixation which was previously discussed. A standardized approach that limits distal junctional pathology has yet to be devised. However, the literature does have some significant recommendations. Lee and colleagues suggest that the number of rods crossing the lumbopelvic junction likely increase construct stiffness without creating a stress riser at the junction and found that higher number of rods and an accessory rod to LIV of S2 or ilium was protective against pelvic fixation failure.[11]

Interbody fusion in the junctional segment can also be utilized to provide greater lordotic correction while simultaneously enhancing the stiffness of the construct allowing the segment to withstand mechanical stresses after fusion and providing indirect neural decompression. While the use of interbody devices has proliferated in deformity surgery as means of correction the evidence remains equivocal. In a meta-analysis, Cavagnaro and colleagues conclude that the widely adopted use of interbody fusion at L5/S1 in long fusion is unsupported in a review of 12 retrospective studies containing 1216 patients. The primary outcome defined as pseudarthrosis rate was reported as having no difference between those receiving and not receiving interbody fusion.[7] Similarly, McDonnell et al reviewed risk factors for DJF in ASD and found no difference in the rate of DJF in those receiving interbody fusion and those not concluding it is not a risk factor for DJF, however, there was heterogeneity of levels and technique included in analysis.[3] More high-quality investigations are necessary to understand the effect of interbody fusion on DJF. The authors of this article regularly use interbody devices and support their use in the lumbar spine for deformity correction and indirect neural decompression.

When index surgery requires fixation to the pelvis there are a variety of factors that can be addressed to avoid pelvic fixation failure. Historical pelvic fixation failure rates have been reported as high as 36%.[39] Recently Lee and colleagues published 2 year results of pelvic fixation in 253 patients with a failure rate of only 4.3%. The authors investigated protective strategies against pelvic fixation failure and found significant support for multiple rods across the lumbosacral junction and accessory rod LIV to ilium/S2 (Fig. 4). Additionally, it was suggested closed headed screws, larger diameter pelvic screws, longer length pelvic screws, and cobalt chrome rods may be protective when evaluating the much lower fixation rate against historical outcomes.[11] In prior investigations, Guler and colleagues found higher rates of failure in S2AI fixation versus iliac fixation, however, it should be noted the authors used titanium rods and open head pelvic screws which may account for the screw disengagement and rod breakages that were seen in the study.[39]

ANATOMY

While numerous risk factors have been identified for DJK, it is biomechanically the breakdown of the transition point from the rigid fused segment to the unfused mobile spine. This transition point becomes an axis of rotation on which flexing deforming forces can ultimately exceed the ability of the instrumentation-bone interface or adjacent disc to resist. When the spine is well-balanced and an appropriate fusion level is chosen, the distance from the LIV (the axis of rotation) to the force applied by the weight of the fused body segment is small (Fig. 5). Therefore, there is a small amount of torque across the LIV and a decreased risk of DJK. When the spine is fused to a more proximal kyphotic segment, the moment arm from the LIV to the force applied by the weight of the body segment is increased, leading to increased torque across the LIV and a higher risk of DJK. This may

Fig. 4. The author's preferred fixation is shown when fusing to the sacrum.

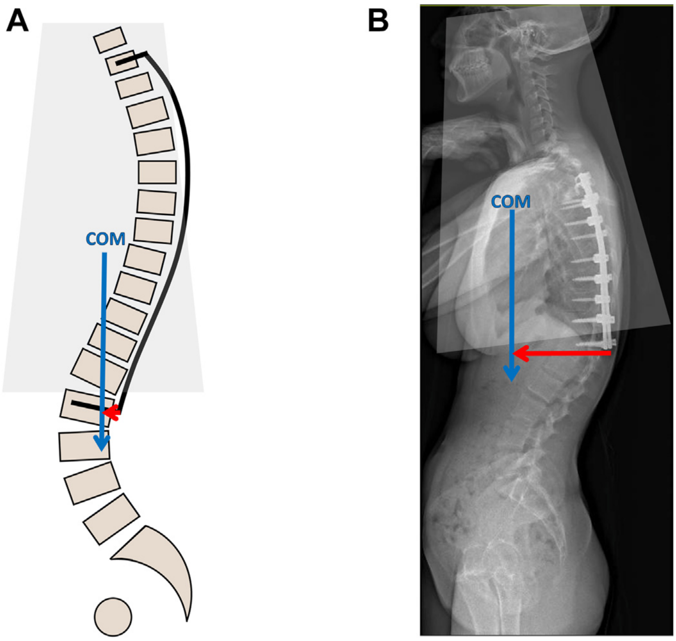

Fig. 5. A shows a balanced spine with a fusion construct from T2-L2 and B shows a fusion construct from T4-T12 with radiographic DJK. The gray trapezoid represents the body mass above the LIV. "COM" represents the center of mass of the body above the LIV, with the blue arrow representing the force vector of the center of mass. The red arrow represents the lever arm of the LIV. In A, the moment arm from the center of rotation of the LIV to the force vector of the COM is small, resulting in a small amount of torque across the L2-L3 segment. In B, there is a much larger moment arm from the center of rotation of the LIV, resulting in a large amount of torque across the T12-L1 segment. This torque ultimately caused rotation around the LIV resulting in DJK.

explain why increased rates of DJK are seen when an LIV is chosen that is proximal to the SSV in AIS and Scheurmann's Kyphosis.[17,19,35–37,40]

It has also been shown that longer fusion constructs, especially those with an LIV at L5 or S1 without pelvic fixation increase the risk for developing DJK.[3,41,42] It is well known that long fusions in ASD to L5 significantly increase the risk of L5-S1 degeneration.[43] The increased weight of the body segments above the LIV as well as fewer mobile segments to compensate for changes in posture contribute to increased junctional stress. This is especially true with sagittal malalignment. When sagittal malalignment is not restored in a long fusion resulting in positive sagittal imbalance, a larger moment arm results in significantly more force transmitted through the LIV from the entire weight of the rigid fusion segments above (**Fig. 6**). The resulting junctional stress results in subsequent disc degeneration, further exacerbation of positive sagittal imbalance, and the ultimate development of DJK.[43,44]

Patient-specific factors such as anatomic variation in the L5 vertebra are also speculated to play a role in the development of DJK. Edwards and colleagues[44] examined a series of patients with ASD fused to L5 and found that the depth of L5 within the pelvis was a significant risk factor for loss of L5 fixation, where an L5 depth of 12 mm or more led to an implant failure rate of 55%. The authors hypothesized that a deep-seated L5 provided stability to the L5-S1 motion segment with fusions ending at L5, thus concentrating stress at the L5 bone-implant interface.[44]

PREOPERATIVE/PRE-PROCEDURE PLANNING

A surgical plan should be defined prior to entrance in the operating room to facilitate efficiency and safety. Obviously, this plan must account for the unique characteristics of each patient including etiology of deformity and goals of correction.

With regard to distal junctional pathology the major preoperative/planning steps involve deciding the distal level of fusion and the method of fixation. As previously described, there is literature to help make these decisions. In certain cases, classification systems have been developed to help guide the decision, such as the Lenke Classification for Adolescent Idiopathic Scoliosis.[45,46] In other areas such as ASD, as many patients are fused to the sacrum the decision is more focused on the method of fixation. In isolated thoracic hyperkyphosis, the literature is less consistent on level selection; however, the authors' preference is to fuse to at least the SSV.

A few consistent rules for the distal LIV selection can be applied regardless of the etiology and surrounding patient characteristics:

- It is necessary to understand the deformity and magnitude of correction required
- The planned distal fusion level should not have substantial degeneration, instability, or kyphosis
- Preservation of the posterior ligament complex at the distal segment is necessary
- In the setting of a preoperative fusion mass, the fused area should be restored to normal

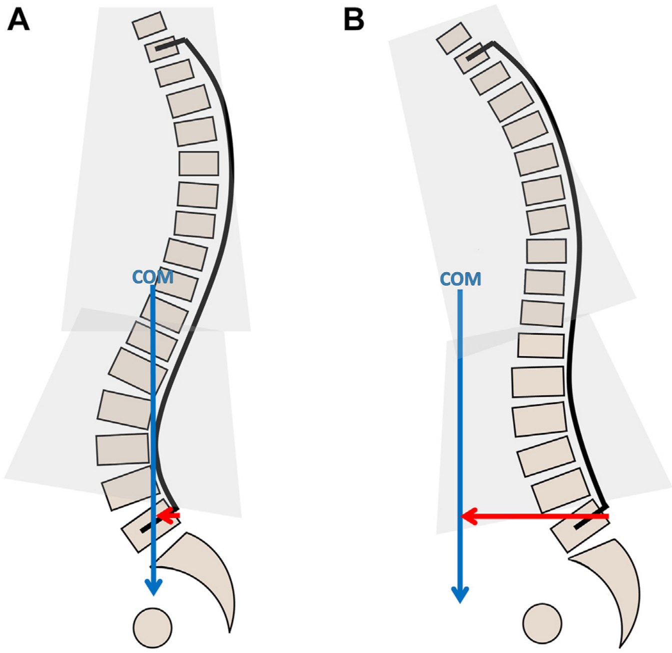

Fig. 6. A shows a balanced spine with a fusion construct from T2-L5. In A, the moment arm from the center of rotation of the LIV to the force vector of the COM is minute, resulting in a minimal amount of torque across the L5-S1 segment. B demonstrates a construct with the same levels as A with failure to restore appropriate lumbar lordosis. The result is a larger moment arm from the LIV to the COM force vector, indicating a significantly larger amount of torque at this level. Over time it is expected that the higher torque resulting from sagittal imbalance will result in the development of DJK with subsequent increases in torque across the LIV as the deformity worsens.

alignment if possible. This may be achieved with planned osteotomies.

PREP AND PATIENT POSITIONING

The authors preferred skin prep includes a 4% chlorhexidine gluconate mechanical scrub that is removed with a clean towel followed by a 70% alcohol solution that is allowed to dry on the skin followed finally by a chlorhexidine gluconate and isopropyl alcohol skin prep applicator prior to draping. After draping an additional chlorhexidine gluconate and isopropyl alcohol skin prep applicator is used again followed by an iodine impregnated adhesive over the entire surgical area. Standard patient positioning is demonstrated in the included images. Special attention is paid to padding all bony prominences. Regarding room set up, all surgical electronics are run to power sources at the foot of the patient. The surgical instrument table is set up behind the primary surgeon with the surgical technician and mayo stand on the same side at the foot of the patient. The first assistant is on the opposite side. If robotics or intraoperative imaging are to be used they are brought in from the first assistants' side.

PROCEDURAL APPROACH

Adult spinal deformity

- Long fusion should be extended to the sacrum or pelvis in the following cases:[47]
  - Poor bone quality
  - Spondylolisthesis or degenerative disease at L5-S1
  - Sagittal imbalance
  - Lumbar hypolordosis
  - Concomitant coronal plane deformity
  - High pelvic incidence[9]
  - Prior laminectomy at L5-S1[48]
  - Oblique take-off at L5-S1[48]
- When fusing to the sacrum or pelvis
  - Consider interbody structural support at L5-S1 and other lower lumbar levels on a case by case basis[7]
  - Consider accessory rods and if utilizing, S2/ilium is the preferred LIV[11]
  - Consider the use of multiple pelvic screws to enhance pelvic fixation[49]
  - Use wider diameter and length pelvic screws. At least 8.5-mm and 85-mm is suggested
  - Aim for minimal residual coronal malalignment to avoid pelvic fixation failure[11]
  - It is highly recommended that S1 pedicle screws be tricortical, especially in elderly patients, and should be directed medially in the sacral promontory for both greater insertional torque and safe application[48,50]
  - Preserve the posterior ligament complex of the distal junction segment if fusing short of the sacrum

Adolescent Idiopathic Scoliosis

- Consider utilizing the LTV rather than LSTV to preserve an additional motion segment in mature patients

- When there is discordance between the SSV and the LTV, fuse to the more distal segment to decrease risk of junctional pathology
- Consider determining LTV and SSV on supine radiographs to assess curve flexibility and spontaneous curve correction

Thoracic Hyperkyphosis/Scheuermann's Kyphosis

- Fusion to the SSV, FLV+1, or FLV+2 should be considered to maximize avoidance of clinically significant DJK/DJF[17–19]
- Patients with thoracic type Scheuermann's Kyphosis, consideration of fusion above the SSV to the FLV can be considered[20]
- Preserve the posterior ligament complex of the distal junction segment

RECOVERY AND REHABILITATION (INCLUDING POST-PROCEDURE CARE)

While much has been published on postoperative measures after spine surgery such as enhanced recovery protocols and surgical site infection avoidance, little to no literature has been published on recovery and rehab protocols to aid the avoidance of distal junctional pathology. As such no standardized protocol has been implemented; however, there are commonsense principles that can be applied to any patient undergoing spine surgery where DJK/DJF is a concern.

- Initiation of physical therapy to aid cuing the patient to adopt an erect sitting position and activation of extension muscles as soon as permitted
- Avoidance of passive flexion in the junctional segment
- Patient education on safe ergonomic practices such as avoiding lifting weights at a distance from the body, and knee flexion instead of back flexion when picking an item off the floor
- Consideration of walker use to decrease the flexion moment in patients with an unbalanced trunk
- Consideration of a brace to protect the distal junction from flexion for a limited time period post operatively[51]

MANAGEMENT

When distal junctional pathology occurs it may or may not need to be addressed depending on the etiology. Asymptomatic distal junctional kyphosis may not always need intervention, but it can be considered if it is thought to be the initial finding in a trend toward distal junctional failure. Other pathologic etiologies that are less equivocal which should be intervened upon include junctional failure from fracture or implant-related issues.

In general, distal junctional failure should be addressed on an individual basis, but the following principles can guide treatment:

1. Restore alignment
2. Decompress any stenotic areas
3. Improve mechanical support at the failed junction
4. Extend the construct distally (if able, as many long constructs end in the ilium during the index procedure)
5. Select a new distal sagittal stable level in patients initially fused short of the sacrum. Ensure the level is stable coronally and rotationally as well.

Improved mechanical support can be achieved by multiple methods. This can include adding additional rods in accessory, kick-stand, or delta rod configuration. Additionally, anterior interbody devices can be added to off load posterior constructs of the junction segment. Upsizing distal screws can also be considered.

OUTCOMES

Outcomes for distal junctional pathology avoidant strategies

Distal junctional pathology avoidant strategies often select for longer constructs and more significant fixation distally such as iliac fixation. The argument against such constructs is that it fuses a greater number of segments decreasing spine mobility and increases operative morbidity.

In ASD, outcomes reported on DJP avoidant strategies suggest patients need to be evaluated on a case-by-case basis as there are unique advantages and disadvantages of lumbar fusion versus sacro-iliac fusion with regard to complication avoidance.[3,52,53] Additionally, the evidence is not always consistent. In a meta-analysis of 12 studies assessing risk factors for DJF in ASD, it was found that fusion stopping at L5 compared to the sacrum was at increased risk of DJF (11.6% vs 3.7%).[3] A higher DJF rate would imply a higher revision rate. However, in another meta-analysis of 11 studies, no significant difference in overall complication rate and revision surgery rate was noted between fusing to the sacrum or L5.[52]

After deciding to fuse to the sacrum in ASD patient, outcomes are more clear that iliac fixation is most beneficial in avoiding distal junctional pathology with improved sagittal balance and no detriment to patient-reported outcomes.[11,54,55]

Outcomes reported on thoracic hyperkyphosis and AIS appear to be more consistent. Most reports agree that fusing to at least the SSV provide a significant advantage in reducing DJP.[17,18,40] In AIS, recent outcome literature focused on the sagittal plane suggests fusion to the SSV is most protective against DJP.[35–38]

Outcomes after distal junctional pathology revision surgery

Clinical and radiographic outcomes related to revision surgery for DJK are currently lacking in the literature. Further research is necessary to determine the optimal management of patients in whom DJK develops.

While emerging literature is identifying risk factors for DJK as well as strategies to avoid it, the outcomes of these strategies are a necessary area of further study. This is especially true as these strategies may demonstrate further consequences. For example, in long fusions in the setting of ASD, fusion to the sacrum vs L5 in patients without L5-S1 degeneration results in a higher reoperation rate, particularly for pseudarthrosis, and an increased rate of medical morbidities such as pulmonary embolism.[13] Therefore, the risk of subsequent DJK must be weighed against the risks of extending the fusion to the sacrum in this population. However, among these patients, patient-reported outcome scores are similar.[13] It has also been shown that the addition of iliac fixation to long fusions does not have a negative influence on patient-reported quality of life.[55] Further high-quality studies are required to analyze the effects of these and other DJK avoidant strategies on patient outcomes.

SUMMARY

Distal junctional pathology remains an unsolved problem in spine surgery. There is no definitive answer regardless of deformity etiology, however, there is a growing literature which suggest strategies to avoid it. When DJP is encountered, it can be on a spectrum from asymptomatic radiographic finding or marked distal construct failure necessitating early revision. Asymptomatic radiographic findings, however, may be the first step toward total failure. Utilizing the literature focused on avoiding distal junctional pathology along with basic principles of deformity correction will improve outcomes. Distal junctional pathology requiring revision surgery should focus on restoration of alignment and improved mechanical support at the level of pathology and distal extension as is usually required.

CLINICS CARE POINTS

- Avoiding Distal Junctional Pathology
  - In all scenarious, preserve the posterior ligament complex of the distal junction segment.
- Adult spinal deformity
  - Extend fusion to the sacrum in the setting of any lumbar pathology that may predispose to failure such as osteopenia or disc space degeneration
  - Consider accessory rods across the distal junction and if utilizing, S2/ilium is the preferred LIV[11]
  - When fusing into the sacrum, consider using sacro-iliac fixation to reduce the risk of distal junctional pathology
  - Cobalt rods, closed head screws, larger diameter screws, and longer screws for pelvic fixation may be protective against failure
- Adolescent Idiopathic Scoliosis
  - When there is discordance between the SSV and the LTV, fuse to the more distal segment to decrease the risk of distal junctional pathology
- Scheuermann’s Kyphosis
  - Fusion to the SSV, FLV+1, or FLV+2 should be considered to maximize avoidance of clinically significant DJK/DJF[17–19]

DISCLOSURE

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