

# High-Grade Pediatric Lumbar Spondylolisthesis: Expert Panel Approach

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## Introduction

There are several approaches to pediatric high-grade (>50% slip) lumbar spondylolisthesis treatment. Nonoperative management has been advocated for minimally symptomatic patients, particularly if the slip angle is low (20 degrees vs. 34 degrees).<sup>1-3</sup> Surgical treatment of symptomatic high-grade slips has evolved from noninstrumented in situ fusion, which carried a high risk of slip progression and lower self-image, yet minor long-term functional differences.<sup>4-9</sup> Modern approaches include instrumented in situ fusion with or without trans-sacral Bohlman technique;<sup>10-11</sup> anterior approach and interbody fusion; and posterior approach with or without reduction, with or without circumferential fusion by interbody anterior column support.<sup>12-17</sup> A 2017 Scoliosis Research Society (SRS) Evidence Based Medicine Committee review recommended instrumented reduction and circumferential fusion for lowest nonunion risk but could not offer recommendations on more specific surgical and perioperative details.<sup>18</sup> This also did not review the most recent literature that has emphasized and refined the importance of sagittal plane alignment to classify, determine treatment plan, and evaluate the surgical result.<sup>19-28</sup> This new focus includes percent slip, global sagittal balance, and lumbosacral parameters to ascertain degree of severity and pelvic balance.



**Figure 1.** Expert Panel

We asked three experienced spine clinicians and leaders to review a spondylolisthesis case and give their treatment opinions (Figure 1).

- David Lebel, MD, PhD served as the Head of Pediatric Spine Service at Dana-Dewek Children's Hospital Tel-Aviv before relocating to The Hospital for Sick Children.
  - Robert Cho, MD is a Pediatric Spine Surgeon, Chief of Staff at Shriners for Children Medical Center—Pasadena, and Chief of Staff at Shriners Ambulatory Clinic—Tijuana.
  - M. Timothy Hresko, MD, who has published extensively on the topic, is Director of Spine Research and Quality Improvement at Boston Children's Hospital.
- Together they have over 50 years of experience treating complex spine disease. Responses were edited for length and repetition of the same points.

## Case

A 12-year-old female presented with a two-year history of low back pain. This worsened over the last 6 months with bilateral posterior thigh/buttock shooting pain whenever standing more than 15 minutes or any attempt to flex forward at the waist. On exam, she has bilateral straight leg raise at 30-degree knee flexion, popliteal angles over 70 degree, and normal strength, sensation, and reflexes in L2-S1 dermatomal distributions. Upright spine radiographs show a Meyerding Grade III L5 spondylolisthesis and positive sagittal balance (Figure 2). Computed tomography (CT) and magnetic resonance imaging (MRI) show some reduction of the slip while supine, a domed sacrum, and dysplastic lumbosacral posterior elements (Figures 3, 4). Spinopelvic parameters and their measurements are shown in (Figure 5).

## Case Questions and Expert Guidance

***Is there a role for nonoperative intervention?***

***When would surgery be indicated?***

All experts would offer nonoperative treatment of activity restriction and physical therapy in this patient since there are no neurologic deficits or cauda equina symptoms, which would be absolute surgical indications, and the doming is evidence of slow progression. If, after a period of rest and rehabilitation the symptoms return, and changing future activity is not acceptable, then surgery is offered.

**Hresko:** In general, low-grade spondylolisthesis with a normal pelvic incidence (PI) of near 50 degrees are treated nonsurgically while patients with high-grade slip of greater than 50% and lumbosacral angle of Dubousset (Dub-LSA)  $<90^\circ$  are consider as potential surgical candidates [*Dub-LSA is the angle subtended by the posterior cortex of S1 and the superior endplate of L5<sup>29</sup>; this is different from Spinal Deformity Study Group's and inferior endplate of L5<sup>24</sup>*].

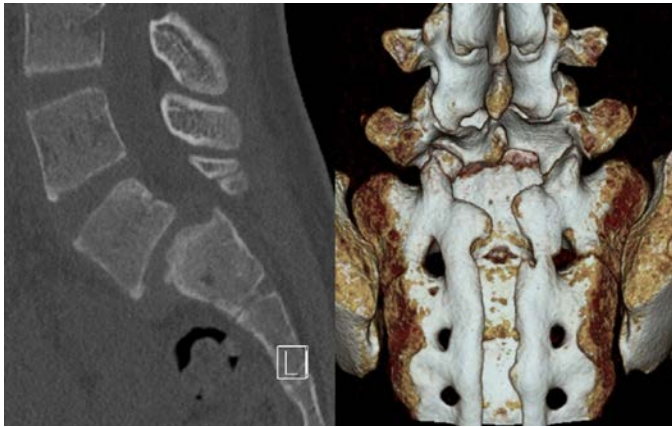


**Figure 2.** Presenting radiographs AP/lateral spine.

***How do clinical findings and imaging influence your treatment strategy?***

All our experts use preoperative CT for bony detail, including detecting intact dysplastic pars that increase neurologic risk with slip, and MRI for neurologic detail. However, differences exist for the radiographic interpretation.

**Lebel:** Preoperative CT helps with planning anchors especially the L5 screws. Understanding the integrity of the posterior elements will help to decide preoperatively between Jackson fixation or S2-Iliac screws. The CT and MRI are done supine and help with indirectly understanding the reduction potential prior to any instrumentation at all.



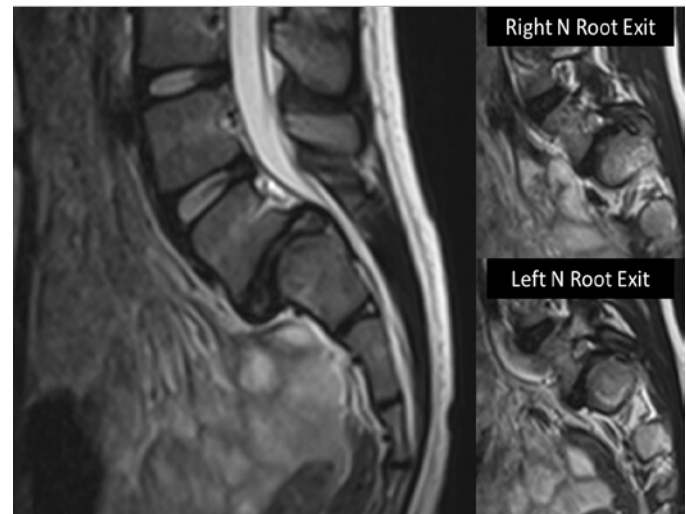
**Figure 3.** Preoperative CT

**Cho:** A high-grade slip (Meyerding Grade III and above), domed sacrum, and a high sacral slope angle, as seen here on x-ray, make me much more likely to consider surgical intervention, as these would make it more likely to continue to slip.

**Hresko:** Appropriate imaging is especially important in order to understand the regional and global sagittal posture. My standard radiology request is for standing PA and lateral spine C7 to femoral heads and standing spot lateral of lumbosacral spine. I do not routinely include the hip-to-ankle imaging, which is possible in the slot scanner, unless my physical exam finds fixed flexion contracture at the hips or knees. I pay close attention to the pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) in order to place the patient into the Spinal Deformity Study Group (SDSG)<sup>19, 21, 22</sup> classification. The anterior translation of the cephalad vertebrae and the Dub-LSA (normal 110-115 degrees) reflect the regional deformity and can be accurately measured in the operating room to assess your reduction when performed.

**What tips do you have on measuring SS/PI with a domed sacrum?**

**Cho:** I use the tip of the sacral promontory anteriorly and the posterior superior corner of the S1 vertebra as my two points to create a best fit endplate line.



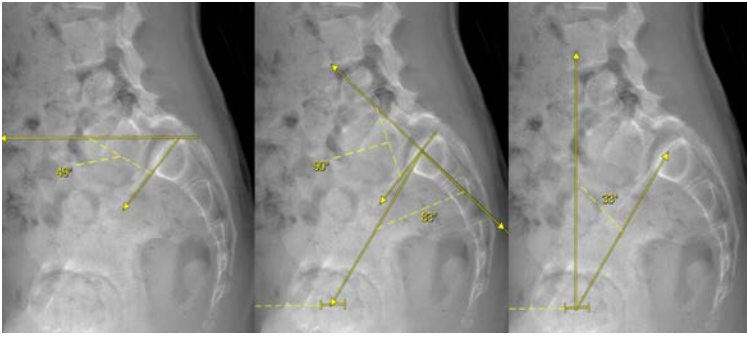
**Figure 4.** Preoperative MRI including sagittal cuts through the L5 foramen.

**Hresko:** I follow the recommendation of the SDSG system<sup>21</sup> which is now available through the SRS.org website. Measurement of PI, SS, and PT are less reproducible when dome sacrum is present. In that situation, measurement of Dub-LSA, L5 incidence, and global balance become more influential in deciding treatment as those measurements are not influenced by the shape of the sacral endplate.

**What would be your surgical approach for this patient?**

**Lebel:** L4-S1 posterior spinal fusion. After S1 screws (large 6.5/7.5 mm bi-cortical) I will do a Jackson technique [*extending the rods distal into the sacral lateral masses*]<sup>30</sup> as another anchor (Figure 6).

**Cho:** L5-S1 posterior spinal fusion with instrumentation with a transforaminal lumbar interbody fusion (TLIF) or posterior lumbar interbody fusion (PLIF). This allows you to get direct decompression of the L5 nerve roots with visualization the entire time as you are reducing the slip. I think it is critical to provide anterior support with a cage if you are performing a significant translation or angular change maneuver; otherwise, the posterior



**Figure 5.** Preoperative lumbopelvic measurements: Sacral Slope (SS) 49 degrees, Pelvic Incidence (PI) 83 degrees, Pelvic Tilt (PT) 33 degrees.

screws will likely be put under significant stress and may break before the fusion is complete.

**Hresko:** The goal of surgery for patients with spondylolisthesis is to reduce back pain and nerve irritation from stenosis or stretch. The SDSG classification is helpful to plan a surgical approach. Her sagittal profile of approximately 50% translation, PI >70, and pelvic positional parameters would place her as a type 4 as she has acceptable global balance.<sup>21</sup> A posterior in situ fusion might alleviate her back pain, but I would recommend that a decompressive laminectomy with bilateral foraminotomy should be performed due to her hamstring tightness. Her symptom of pain on flexion is more typical of foraminal stenosis as compared to pain on extension due to pars insufficiency. An instrumented reduction with grafting of L5 transverse process to sacral ala after decompressive laminectomy and foraminotomy has risk of nonunion so I would also add a PLIF with anterior structural support.

#### ***How do you position the legs during surgery?***

All surgeons place legs extended with 45 degrees (Cho) or 30 degrees (Hresko) hip flexion.

#### ***Reduction vs. in situ fixation?***

***If reduce, what guides your decision for amount of reduction?***

#### ***What do you look for intraop to be satisfied?***

#### ***Do you decompress no matter which approach?***

**Lebel:** I will use positioning, some S1-L4 distraction, and then minimal pull on L5 screws. Usually this is enough for some reduction and correction of the slip angle (Figure 6). If during this gentle reduction attempt, the patient has neuromonitoring changes, I will bend the rods better to reduce my reduction. If this continues to cause signal change, then I will decompress and do foraminotomy to release. Our group recently reported the slip angle correction and resolution of preoperative radiculopathy obtained from this gentle reduction.

**Cho:** When I think of reduction, I think of both translation and angular change of the L5 vertebral body. Of the two, the angular change is more important to overall outcome and can be done with less stretch on the L5 nerve root and will forgo translation to protect the roots. I aim for 50-75% translation correction and near 100% L5 angular correction. For this case, the lower slip percentage causes less concern for the L5 roots, so I would aim for 100% translation correction. It is critical to decompress the L5 nerve roots if a reduction maneuver is being planned. Visualizing the roots during the entire reduction allows you to see them stretched before any motor changes occur.

**Hresko:** A reduction to less than 50% translation will allow for placement of anterior support and bone graft between L5- S1 endplates. I confirm <50% translation and Dub-LSA>90° on intraoperative fluoroscopy, which are correlated to obtaining a successful L5-S1 fusion. I decompress if there are nerve irritation signs. If the patient had low-grade spondylolisthesis and pain on extension, then I would do an in situ fusion without decompression.

#### ***Instrumented vs. noninstrumented fusion?***

Each surgeon always instruments.



***Fusion location – anterior, posterior, interbody?***

**Lebel:** Posterior and posterolateral over the transverse processes (TPs)

**Cho:** Almost always posterior approach with TLIF. I have seen complications including ureter injury from surgeons performing anterior lumbar interbody fusions (ALIFs).

**Hresko:** My standard is posterior fusion of lumbar transverse process to sacral ala with local graft from superior ala and iliac crest. A PLIF is added when transverse process is small, or laminectomy is performed.

***Fusion Levels – When do you extend to L4? Do you fuse to L4 or reduce and exchange shorter rod and remove? When do you consider sacral alar-iliac (SAI) instrumentation?***

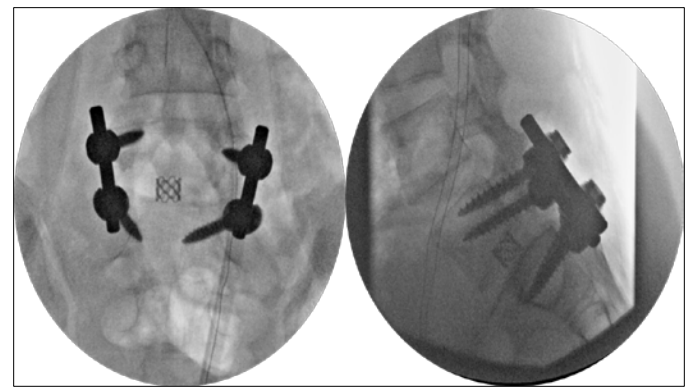
**Lebel:** I always fuse to L4 on high grades. SAI will be used if I cannot do Jackson technique. For example, if there is a large posterior element defect that extends to the sacrum.

**Cho:** For a very high-grade slip, especially for grade 4 or 5, I will often go to L4 for stronger fixation and better ability to provide further lordosis. I would utilize SAI screws for a grade 5 spondylolisthesis or if I felt my bone quality was subpar but even then bicortical S2 screws can be a better option.

**Hresko:** I do not use SAI screws in this age group. If supplemental pelvic instrumentation is needed, I would place iliac screws, with the planned removal 1-2 years after surgery. We found removal of pelvic implants as the most common reason for secondary surgery for spondylolisthesis. I recommend fusion to L4 when L5 fixation is marginal, Type 6 deformity, or reduction does not reduce translation to <50%.



**Figure 6.** Example of slip corrected with only gentle reduction and Jackson technique of distal sacral rod fixation per Dr. Lebel's discussion.



**Figure 7.** Final intraoperative radiographs.

***If performing an interbody fusion, do you use instrumentation?***

**Lebel:** I try to avoid that. I do not see a huge advantage.

**Cho:** I think cage choice matters less than the idea of providing structural anterior support; I prefer a PEEK cage with local autograft.

**Hresko:** My preference for restoring lumbosacral lordosis and maintaining adequate L5 foramen space is the use of an interbody device and posterior compression instrumentation. The interbody device size and shape depends on the amount of residual translation after reduction. For very young patients under age 10, I may use iliac graft without implant, but I am more likely to customize a metal cage.

**What type of graft do you use and where do you place it?**

**Lebel:** I use iliac crest autograft posterior and posterolaterally, from L4 transverse processes to the sacrum. Occasionally, if I had to perform discectomy, I will add some bone graft anteriorly.

**Cho:** I use local autograft from decompression, as well as some demineralized bone matrix and allograft corticocancellous chips in the posterolateral gutters, just lateral to the screws. It is critical to visualize the transverse processes at L5 and the sacral ala to decorticate them to prepare for fusion.

**Hresko:** I use iliac crest autograft to supplement the bone obtained from laminectomy and allograft.

**What is your postoperative protocol?**

**Lebel:** Because I usually go longer than L5-S1 both proximally and distally, I feel that I have more stability and then will avoid using any kind of braces.

**Cho:** I recommend a soft brace with 6 weeks bending/lifting twisting restrictions; patients are cleared for light exercise at 3 months and all restrictions removed at 6 months.

**Hresko:** My patients are given an anterior opening lumbosacral orthosis for 3 months.

**What are the most common errors you see made? How can surgeons avoid them?**

**Lebel:** Trying to get great anatomical reduction and paying the price of significant neuro-monitoring fluctuation during the case. Avoiding complications starts with understanding that high grade spondylolisthesis is not a single pathology. Having a fixed plan for all spondylolistheses is detrimental. Each one is different, and therefore impossible to have only one plan unless you fuse all of them in situ with no instrumentation. Whenever you start to reduce or correct



**Figure 8.** One-year postoperative global sagittal alignment.

the slip angle, you need some back up plans to deal with the consequences.

**Cho:** Lack of anterior support with some type of cage, and incomplete decompression and visualization of the L5 nerve roots. Anterior support is critical to prevent screw failures and pseudarthrosis. Decorticating the endplates at L5-S1 and making sure to remove all disk material between the endplates and the cage allows for fusion to occur more reliably. Incomplete decompression of the L5 nerve roots means that you cannot see what is happening to

them as a translation maneuver is performed which places considerable stretch on them. Visualizing these helps you determine how much stretch you are putting on the roots before a neuropraxic injury occurs.

**Hresko:** By far, the most common error is lack of adequate restoration of lumbosacral lordosis. The surgical goal should be to obtain lumbosacral lordosis (Dub-LSA > 90°). It may be difficult to measure the angle on fluoroscopy while in the OR so it is reasonable to image final construct with intraoperative CT. The L5 incidence may be easier to measure. This represents the ‘neo- pelvis’ as described by Roussouly.<sup>31</sup> Ideally the L5 incidence should be <65 degrees.

## Case Outcome

The patient was treated with bilateral L5 nerve root decompression, S1 dome osteotomy, partial reduction, and L5-S1 instrumented PLIF with iliac crest autograft harvest (Figure 7). She was discharged home postoperative day two and has done well without

**Table 1. Summarized Expert Surgical Approach**

|                         | <b>Lebel</b>  | <b>Cho</b>  | <b>Hresko</b>   |
|-------------------------|---|---|---|
| <b>Instrumentation</b>  | always  | always  | always  |
| <b>Construct</b>        | L4-S1 + Jackson sacral technique; S2 if needed        | L5-S1; L4 – S2 if needed                                | L5-S1; L4-iliac if needed                             |
| <b>Decompression</b>    | with intraop neuromonitoring changes                  | always  | with preop nerve symptoms                             |
| <b>Reduction goal</b>   | gentle correction of slip angle as safely as possible | 100% corrected slip angle, 50-75% corrected translation | correction to Dub-LSA >90°; 50% corrected translation |
| <b>Interbody fusion</b> | never   | always  | when decompress, or to obtain better lordosis         |
| <b>Postop brace</b>     | never   | soft brace  | front-entry LSO                                       |

complications. One-year postoperatively, she has an improved global sagittal balance (Figure 8) with improvement of spinopelvic parameters (Figure 9).

***What does the panel feel about the result? Here, as with many of these cases, our challenges were placing our screws with enough medial direction and increasing the lordosis; what advice would you offer to improve this?***

All experts agree on the need for more medialized screws. Cho and Hresko recommend percutaneous trans-muscular screw placement if needed to get the correct medialized angle; navigation or robotic assistance may help optimize the position. To improve the lordosis attained, which could also aid in screw placement, Lebel and Hresko recommend extending the distraction over more levels, either by fusing more proximally and distally (Lebel) or with temporary distraction between L3 and the ilium (Hresko). Cho recommended a larger dome osteotomy, more

anteriorly positioned cage, and compression posteriorly over this to improve the slip angle.

## Discussion

For treatment of a high-grade lumbosacral spondylolisthesis, we had consensus from our experts on instrumentation, reduction, and iliac crest autograft or augmented bone graft. Differences were found with instrumentation construct, amount of reduction to aim for, uniform inclusion of interbody fusion, and decompression (Table 1). The literature suggests that posterolateral fusion alone can result in up to a 37% nonunion rate,<sup>9,13-15,32</sup> while circumferential fusion in comparison reduces this<sup>14,15</sup> and reported back pain.<sup>16</sup> Our experts' success without routine interbody fusion may be owed to their meticulous posterolateral fusion technique with iliac crest autograft or secure fixation. Other commonly reported complications are nerve root injuries, and our experts either limit their translational reduction to avoid this stretch or directly visualize the nerve roots.

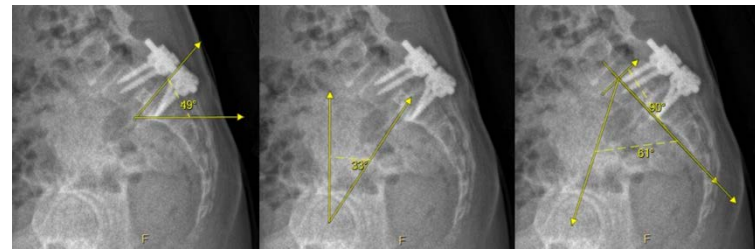
Increased attention to spinopelvic balance has demonstrated certain high-grade spondylolisthesis develop retroverted pelvic orientation and thus unbalanced alignment with a mismatch of low SS and high PT, high slip angle, and loss of lumbar lordosis.<sup>19,20,23,25,26</sup> A large number of measurements can be made on the lumbopelvic relationship, but they may be best simplified here by Dr. Hresko, who uses 90 degree Dub-LSA as cut-off point for surgical indication as well as postoperative goal. Reduction of this deformity to restore lumbopelvic balance is associated with increased fusion rate and improved quality of life.<sup>20,26-28</sup>

## Conclusion

The goal for surgical treatment of high-grade spondylolisthesis is resolution of back pain and lumbar radicular symptoms while preventing slip progression and long-term complications. There are several ways to achieve this and, when choosing treatment, the surgeon must consider the risks and alignment capabilities of each approach. There is growing support that restoration of pelvic balance is an important goal for treatment, no matter the approach.

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**Figure 9:** Postoperative lumbopelvic measurements: SS 49 degrees, PT 33 degrees, L5 incidence 61 degrees.

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