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CASE SERIES

# Single-level fusion without decompression for high-grade spondylolithesis in adolescents: a novel surgical strategy

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## Abstract

**Purpose** There is no consensus on the optimal surgical treatment for high-grade spondylolisthesis (HGS) in adolescents. The purpose of this study was to assess the radiographic and clinical outcomes of a novel surgical approach to HGS consisting of a single-level anterior reduction, placement of a lordotic cage, and circumferential fixation without decompression.

**Methods** This was a retrospective consecutive case series of 11 adolescents who underwent anterior reduction through placement of a lordotic cage followed by posterior fusion using pedicle screws and rods confined to L5–S1. Radiographic data included slip percentage, slip angle, lumbar lordosis, and pelvic sagittal parameters assessed at clinical visits preoperatively and at 2 years postoperatively. A telephone survey was conducted to obtain current information about function, activity level, work status, and retrograde ejaculation.

**Results** Patients were followed for an average of 7.8 years (range 2–16). Mean age was 15.5 years (range 12–19). The mean percent slip corrected from 55 to 18%. The average slip angle was + 17.1° preoperatively and − 14.1° at final assessment (average correction of 20.7°). Thirty-six percent (4/11) of patients improved by three Meyerding grades and an additional 55% (6/11) improved by two grades. Complications included one instance each of superficial infection, wound dehiscence, and transient neuralgia. There were no cases of instrumentation failure, cage subsidence, pseudoarthrosis, or retrograde ejaculation. Radiographic evidence of fusion was observed in all cases.

**Conclusion** Single-level anterior reduction and circumferential fusion without decompression appears to be a safe and effective alternative for the surgical treatment of pediatric HGS.

**Level of evidence** IV.

**Keywords** High-grade spondylolisthesis · Surgical technique · Vertebral slippage · Slip angle · Adolescent · Complications

## Introduction

High-grade spondylolisthesis (HGS), defined as a slip greater than 50% at the lumbosacral junction [1], is rare [2]. While some HGS patients may be asymptomatic, commonly reported symptoms include low back pain and lower extremity symptoms related to compression of the L5 nerve roots or cauda equina including radicular pain and/or a sensory-motor deficit, postural problems, and appearance concerns.

There is no consensus on the optimal surgical treatment for HGS in adolescent patients and numerous strategies have been described [1]. Historically, in situ posterolateral fusion with spica cast immobilization was replaced with pedicle screw fixation [1, 3–6]. However, high rates of failure were reported with reduction and posterior pedicle screw fixation alone [4, 7] which led some authors to advocate extension of the fusion proximally to L4, distally to include the pelvis, or both [7]. Other centers reported decreased failure of fusion with the addition of anterior interbody fusion at L5–S1 [7–12]. Several authors have noted that significant reduction of L5 on S1 can result in L5 nerve root radicular pain or sensory-motor deficit [13–15]. To minimize these complications, a wide decompressive laminectomy, which typically involves removing the loose posterior element of

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L5 (Gill decompression) and extensive bilateral L5 nerve root release, has been recommended before reduction of spondylolisthesis [7, 12, 13, 16]. At our institution, we have found decompression unnecessary when utilizing a novel reduction strategy. We report a consecutive cases series of 11 adolescent patients with HGS who underwent a single-level reduction and circumferential fixation without decompression. The purpose of this study was to assess the radiographic and clinical outcomes of this strategy for treatment of HGS in pediatric patients.

## Materials and methods

### Study design

Retrospective consecutive case series.

### Setting

Single tertiary academic medical center.

### Participants

After institutional review board approval, we reviewed the medical records of consecutive patients aged 12–19 years with HSG who were operated on by the senior author between 7/31/2003 and 5/27/2017.

### Surgical technique

All patients underwent a transperitoneal anterior approach to the lumbosacral junction and placement of a lordotic interbody cage at L5–S1 followed by posterior spinal fusion and instrumentation at the same level during the same anesthesia session. Active reduction of spondylolisthesis was not sought during the anterior approach and the extent of reduction achieved via insertion of trial implants and final interbody cage was accepted as final reduction. No further reduction attempt was made during posterior instrumentation surgery although the pedicle screws were compressed along the rods to aid in the correction of regional kyphosis and cage stability (Fig. 1). A Gill decompression procedure [16] was not performed; rather, Gill's lamina was decorticated as part of the fusion bed. An iliac crest bone graft was harvested and placed in the posterolateral gutters between the decorticated L5 transverse process and sacral ala on each side. Recombinant human bone morphogenetic protein-2 (rhBMP-2) (INFUSE, Medtronic, Memphis, TN) was used for the anterior surgery. The first two patients received double, metallic lumbar tapered cages (Medtronic, Memphis, TN) and subsequent nine patients had polyetheretherketone (PEEK) cages (SpineWave, Shelton, CT).

Neuromonitoring consisted of free-running electromyography to representative muscle groups of L4, L5, and S1 (including the anal sphincter) to detect signs of nerve root irritation. Standard lower extremity somatosensory-evoked potentials, motor-evoked potentials, and H reflexes were continuously monitored throughout the procedure.

### Radiographic and clinical evaluation

All patients had preoperative radiographs as well as magnetic resonance imaging (MRI) and computed tomography (CT) scans. Radiographs included anteroposterior and lateral standing full-length spinal radiographs and a spot lumbosacral lateral radiograph. The slip percentage and slip angle were measured from these radiographs. MRI results were used to exclude spinal stenosis and assess the signal on T2 weighted images at the L4/L5 disc (Fig. 2). A lumbar spine CT scan allowed for direct bony measurements to aid in preoperative planning with specific focus on sagittal alignment. Final postoperative radiographs were taken at least 2 years (range, 24–72 months) after surgery and included a standing full-length spine radiograph, a spot lumbosacral radiograph, and a Ferguson angled anteroposterior (AP)

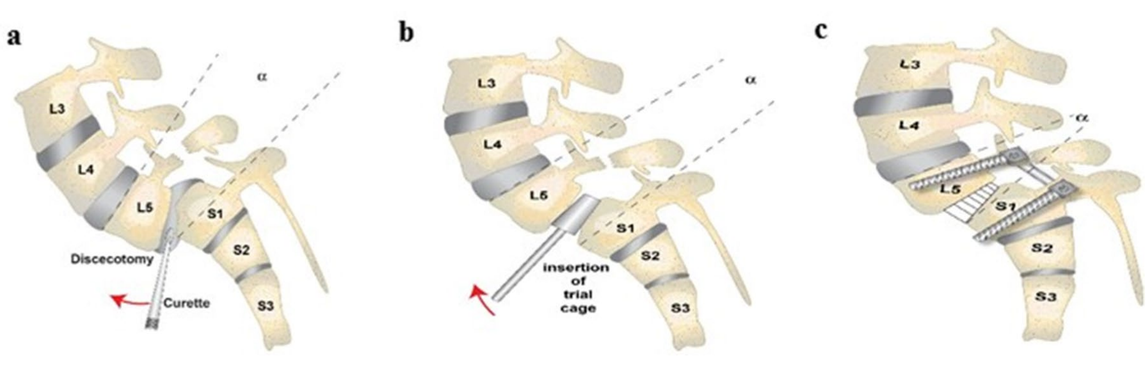


**Fig. 1** Illustration of surgery including anterior discectomy and removal of bony ridge (**a**); insertion of trial cage with reduction of olisthesis and slip angle (**b**); and position of lordotic cage and posterior instrumentation (**c**)

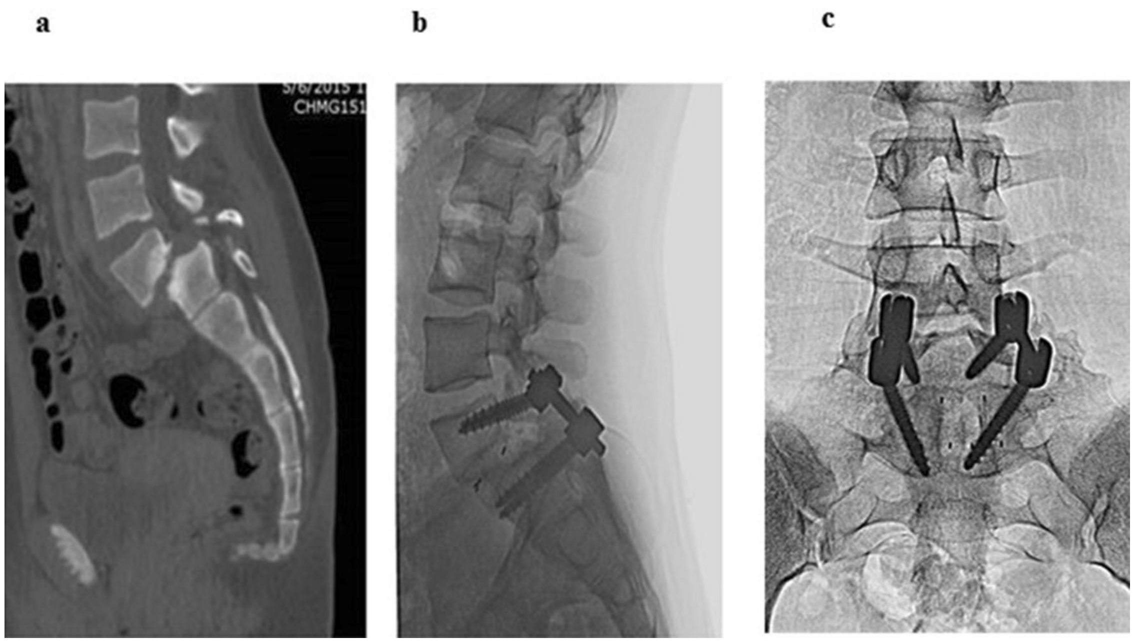

**Fig. 2** Preoperative mid-sagittal cut (**a**), 2-year postoperative lateral (**b**) and AP (**c**) radiographs for patient No. 5 (see Fig. 4)

**Table 1** Patient preoperative characteristics ($n = 11$)

| Characteristic | |
|---|---|
| Age (years), mean (range) | 15.5 (12.3–19.0) |
| Male, *n* (%) | 5 (45.5) |
| Body mass index (kg/m$^2$), mean (range) | 20.8 (18.8–23.9) |
| Meyerding grade 3, *n* (%) | 6 (55.5) |
| Meyerding grade 4, *n* (%) | 5 (45.4) |
| Lumbar lordosis (degrees), mean (range) | 59.3 (48.2–84.1) |
| Sacral slope (degrees), mean (range) | 46.8 (32.5–54.8) |
| Pelvic tilt (degrees), mean (range) | 25.2 (15.0–44.2) |
| Surigcal duration (mins), mean (range) | 340.3 (287–387) |

**Table 2** Individual case changes in Meyerding grade and slip angle from preoperative to 2-year follow-up

| Case | Meyerding grade | | Slip angle (degrees) | | |
|---|---|---|---|---|---|
| | Preopera-tive | Postopera-tive | Preopera-tive | Postopera-tive | Change |
| 1 | 4 | 1 | +4 | −24 | 28 |
| 2 | 4 | 2 | +22 | −4 | 26 |
| 3 | 4 | 1 | +6 | −6 | 12 |
| 4 | 3 | 1 | −29 | −29 | 0 |
| 5 | 3 | 1 | +33 | −1 | 34 |
| 6 | 3 | 1 | +29 | −10 | 39 |
| 7 | 3 | 1 | +8 | −23 | 15 |
| 8 | 3 | 2 | +17 | −3 | 20 |
| 9 | 4 | 1 | +4 | −19 | 23 |
| 10 | 4 | 1 | +20 | −6 | 26 |
| 11 | 3 | 1 | −16 | −30 | 14 |

spot lumbosacral radiograph (Fig. 2). Radiographic measures included the olisthesis percentage and grade, slip angle, sacral inclination, sacral slope, pelvic tilt, pelvic incidence, lumbar lordosis, and sagittal vertical axis. For final follow-up, all patients were contacted by telephone during June 2018 (final follow-up duration range of 24–167 months) to assess for recent updates on function, need for further surgery, work status, and retrograde ejaculation (males only).

## Results

Table 1 describes the preoperative characteristics of the cohort. The average age at the time of surgery was 15.5 years (range 12–19). Prior to surgery, six patients were evaluated as Meyerding grade 3, and five patients were grade 4. The most common presenting symptoms were low back pain ($n = 5$), low back pain associated with L5 radiculopathy ($n = 5$), and concern about a "back hump" with no back pain ($n = 1$).

Table 2 shows the preoperative and postoperative Meyerding grade and slip angle. Olisthesis was corrected to Meyerding grade 1 in 9/11 cases and to grade 2 in 2/11. Thirty-six percent (4/11) improved by three Meyerding grades, 55% (6/11) improved by two grades and 9% (1/11) improved by one grade. The average correction of the slip angle was 20.7°. Preoperative MRI did not show severe stenosis at


a
b
c
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90°
22°
e
R
BR
f
L
g
9°
h
i
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j
k
l

◂**Fig. 3** Preoperative and postoperative imaging and pictures for patient No 2. Preoperative full spine standing AP (**a**) and lateral (**b**) radiographs showing grade 4 HGS and 22° slip angle; preoperative sagittal CT scan (**c**) with sclerotic changes in both endplates as well as dystrophic sacral dome, sagittal MRI T2-sequence image (**d**) demonstrating normal signals in all lumbar discs except for "bilobed" L5/S1 disc as well as spinal canal narrowing at lumbosacral junction; and postoperative AP (**e**) and lateral (**f**) plain radiographs and sagittal CT scan cut (**g**). The free screw was inserted to block loss of position of the interbody cage during turning from anterior to posterior. Postoperative standing AP (**h**) and lateral (**i**) radiographs as well as pictures of range of motion (**j–l**) 6 years after surgery demonstrate the success of the surgery

L5–S1 or significant disc signal change at L4–L5. Mean surgical duration was 340 min (range 287–387).

The average postoperative hospital stay was 3.9 days. All patients were ambulating by the second postoperative day without brace support. Two patients required a second procedure: one required an incision and drainage for a posterior wound infection and one required repair of a posterior wound dehiscence. One patient reported transient neuralgia in the L5 nerve root distribution. There were no cases of persistent neuralgia or sensory-motor deficit. No patient experienced loss of mechanical reduction or fixation, and a fusion mass was radiographically evident in all cases.

The mean follow-up duration was 7.8 years (range 2–16). All patients completed a 2-year follow-up clinical evaluation. Nine of 11 patients completed the telephone assessment conducted at a later date for the purpose of this study. During the telephone assessment, no patient reported pain or interference with daily activities and none of the five male patients reported retrograde ejaculation following surgery. Of the nine patients who completed the telephone questionnaire, two reported not doing any regular specific sport or physical activities (one teacher and one patient with an administrative job). One patient was a nurse who did not complain of any back pain with her regular job and daily life activities as a mother. Five patients were doing high-intensity physical activities, including heavy-duty farm work ($n=1$), competitive swimming ($n=1$; Fig. 3), competitive cheerleading and acrogymnastics ($n=1$; Fig. 4), and regular exercises at the gym ($n=3$). The two patients who did not complete the follow-up questionnaire were students at the time of their last follow-up visit and their current functional status is unknown.

## Discussion

There is currently no consensus on the optimal surgical treatment of HGS in children and adolescents. Most surgeons agree that the goals of surgery are to prevent further slippage by obtaining a solid fusion, restore sagittal balance, and, if possible, preserve lumbar spine motion. This case series presents long-term results for 11 adolescent patients with HSG who underwent single-level lumbosacral circumferential instrumentation and fusion without decompression. Our study shows that improving olisthesis and slip angle can be safely and effectively accomplished through the anterior approach. No patient reported persistent pain or interference with daily activities at final follow-up. All patients achieved solid fusion at the L5–S1 level while preserving motion at the L4–L5 level. All patients reported return to normal activities and two patients reported return to high-level competitive sports that involve significant lumbar motion including swimming (Fig. 3) and gymnastics (Fig. 4). There were no cases of retrograde ejaculation, loss of fixation, cage subsidence, reduction or loosening of instrumentation, or revision surgeries in this cohort.

Sagittal alignment in HGS is affected by both olisthesis and local kyphosis at the L5–S1 level [10, 17, 18]. Patients with HGS maintain their sagittal balance by increasing the proximal femoral angle (PFA) [18] or increasing lumbar lordosis as compensatory mechanisms. Restoration to a more normal PFA in patients with HGS correlates with improvement in quality of life [18]. A persistent positive slip angle, large PFA, and lumbar hyperlordosis in HGS patients with successful fusion can be associated with disabling back pain in later decades.

In this case series, the anterior approach for interbody fusion was carried out first. We observed that meticulous removal of the disc, endplate cartilage, and bony ridge commonly seen on the proximal sacrum allowed for an adequate and often surprising degree of indirect correction of the olisthesis in all patients. No further reduction attempt was needed through the posterior approach and the fusion was confined to the L5–S1 level (Fig. 1). The anterior approach provides much better visualization and space for preparation of the endplates compared to a posterior interbody approach. Reduction of olisthesis to Meyerding grade 0–2 increases the contact surface area between L5–S1, thereby improving the likelihood of fusion. A posterior only approach to reduce HGS may require additional fusion to L4 or the iliac crests to establish more fixation points for a mechanically demanding reduction [4, 7, 10, 12]. In our technique, we did not add L4–L5 to the fusion construct considering the L4–L5 discs did not show degenerative changes in our young patients. We were also reluctant to add sacro-iliac joint fixation to allow for more motion and physical activity. However, achieving strong fixation points via well-positioned and adequately sized screws as well as bicortical S1 screws is crucial. If the bone quality or the strength of fixation points are not satisfactory, additional fixation can be considered. The discectomy should be performed meticulously and the interbody cage placed precisely to provide satisfactory reduction and adequate surface for fusion bed at interbody space.

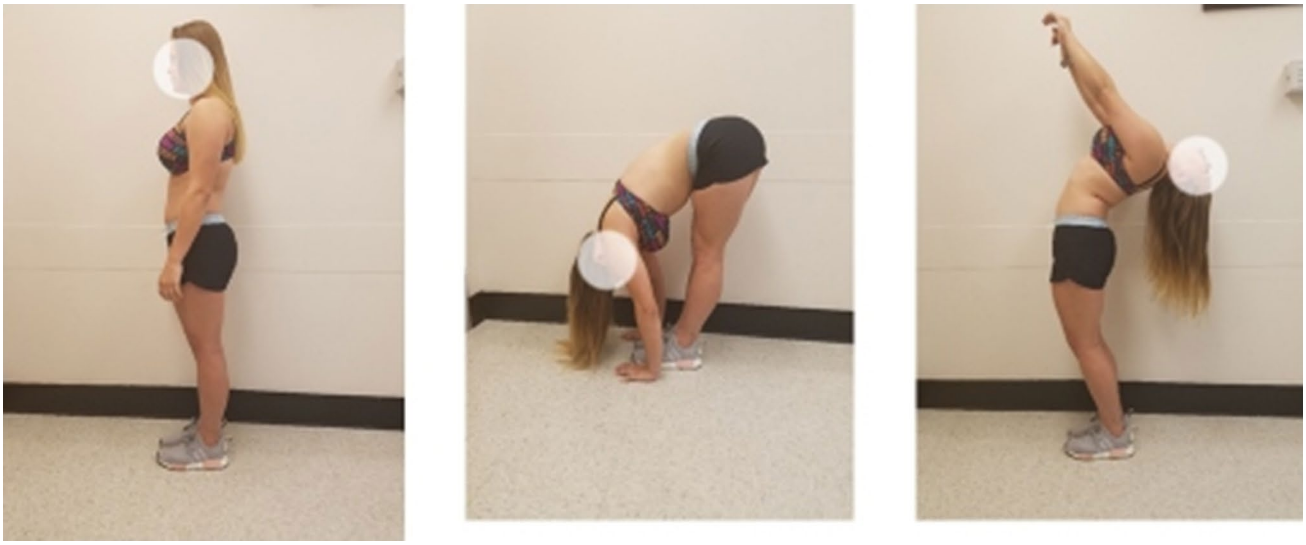

**Fig. 4** Patient (No. 5) returns to competitive gymnastics at 1 year from surgery

Placement of a lordotic interbody cage is important to restore sagittal alignment at the lumbosacral junction, and the anterior approach allows for easier placement of an appropriately dimensioned cage. Placing a lordotic cage with an anterior height of 10–14 mm (normal anterior disc height at L5–S1) using the posterior interbody approach is challenging because a large gap between the posterior endplates of L5 and S1 would be required to accommodate cage placement. Changes to the L5 vertebral body in HGS result in a wedge shape with the anterior cortex often twice as tall as the posterior cortex. Reduction of this elongated anterior cortex without incorporating posterior compression leads to elongation of the middle spinal column. This, in turn, could lead to stretching of the L5 nerve roots, which may be a contributing factor in the L5 neuropathy commonly reported by other authors using a posterior-based reduction strategy [3, 7, 13].

There have been observations that rhBMP-2, which was used to fill the cage in all of our cases, can cause irritation when used in proximity to nerve roots [19, 20]. This would be a significant concern with a posterior interbody approach; however, the nerve roots are not exposed to direct contact with rhBMP-2 in an anterior approach because the dorsal annulus is preserved.

Many authors have expressed concern about carrying out anterior interbody fusion at L5–S1 in young male patients due to the possibility of damaging the lumbar sympathetic hypogastric plexus and causing retrograde ejaculation [21–23]. These sympathetic nerves are small and usually not visible during surgery. To avoid damaging the fibers of the sympathetic outflow, we divided the fascia overlying the L5–S1 disc in the midline and then used soft dissectors to carefully push all soft tissue aside until only the annular fibers were seen. This tissue was held laterally against the common iliac arteries with two Steinmann pins (Fig. 5). None of the five male patients in our cohort reported retrograde ejaculation and two patients became fathers of children during the follow-up period. However, our study sample size is small and retrograde ejaculation still remains as a concern with transperitoneal approach. Although the effects of disrupting the sympathetic outflow in females are unknown, we advocate the same care in protecting the sympathetic outflow in female patients.

The transperitoneal anterior exposure was successful in all cases. There were no cases in which the intended anterior procedure could not be carried out due to anatomic limitations imposed by a high degree of olisthesis or high slip angle. The Pfannenstiel incision was well tolerated by all patients with no incidence of disfiguring scar or scar pain. Some authors have advocated a retroperitoneal approach from the left side through a paramedian incision and mobilizing the left common iliac arteries and ascending lumbar vein [24]. Although it is certainly possible to access the L5–S1 interspace from this approach, it is our opinion that the retroperitoneal approach adds unnecessary difficulty to placement of the lordotic interbody cage and reduction of olisthesis. The literature suggests a higher risk of retrograde ejaculation with the transperitoneal versus retroperitoneal approach, although this might be confounded by other factors, such as surgical technique, meticulousness of dissection, and other factors [6, 23, 25]. It is noteworthy that either the transperitoneal or retroperitoneal approach can be applied in our proposed surgical strategy for treatment of HGS; however, we believe the transperitoneal approach allows for more direct access to the disc and easier placement of a lordotic cage. In either

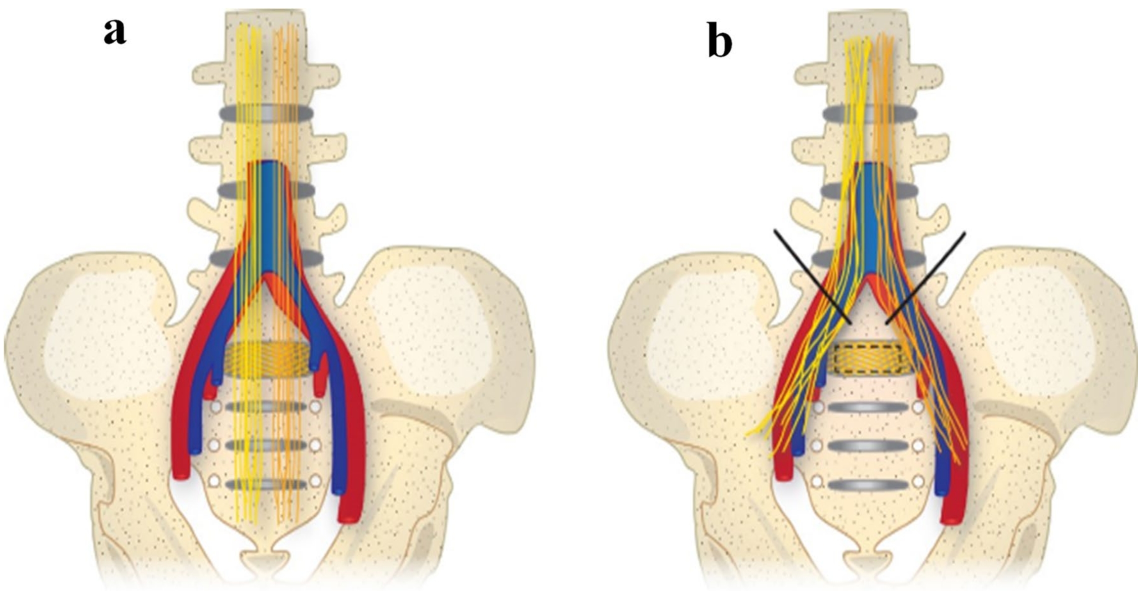


**Fig. 5** Fascia and fibres of the sympathetic plexus are swept to both sides (**a**) and held with Kirschner wires placed in the body of L5 (**b**)

case, blunt dissection and avoidance of electrocautery during the approach are helpful strategies to decrease the risk of autonomic nerve damage and dysfunction.

The posterior approach in this series consisted of supportive instrumentation at L5–S1 without any decompression procedure. However, we believe an important step of posterior instrumentation consists of compression of L5 and S1 pedicle screws through the rods as this helps to secure the interbody cage, shortens the middle spine column, can potentially allow further improvement of the slip angle, and guards against stretching of the L5 nerve roots.

This study has several limitations. First, this is a retrospective case series with the potential for recall bias. Second, the sample size is small as is true for most studies of pediatric HGS due to the rarity of the condition. Because we had no cases with spondyloptosis, our findings may not be applicable to all HGS cases, particularly patients with spondyloptosis. Our single surgeon used a single approach to treat all cases which ensured standardization of procedures and allowed for aggregation of findings. It is uncertain whether the same approach used by different surgeons would yield similar results. Patients who are not experiencing pain and have normal functioning are reluctant to afford time and expense for long-term follow-up. Therefore, we decided to conduct telephone calls for the final follow-up to assess current clinical status. Additionally, patient-reported outcomes were not available for the majority of the cohort. However, a strength of the study was that all patients were clinically followed for at least 2 years and to the point where a solid fusion could be documented.

This study demonstrates the apparent safety and efficacy of single-level anterior reduction of olisthesis and L5–S1 segmental kyphosis and circumferential fusion without decompression for the treatment of HGS in pediatric patients although it may not be applicable to all HGS cases, particularly those with spondyloptosis. Key aspects of success were meticulous anterior preparation and placement of a lordotic cage which allowed simultaneous correction of the slip angle and anterolisthesis. In contrast to previous authors who emphasize posterior reduction techniques, our approach allowed the posterior instrumentation to serve a supportive role and avoided the need for decompression.

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**Authors' contributions** A, H, K: Made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work. A, H, K: Drafted the work or revised it critically for important intellectual content. A, H, K: Approved the version to be published. A, H, K: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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**Data availability** The original/raw data for main outcomes presented in the paper can be found in Table 2.

**Code availability** Not applicable.

## Declarations

**Conflict of interest** Dr. King reports having received payment from by Medicrea to attend a meeting outside the scope of this work. All other authors have nothing to disclose.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Approval was granted by the Institutional Review Board of the University of Louisiana Health Sciences Center (FWA 00002762).

**Informed consent** In view of the retrospective nature of the study, the fact that all the procedures and measures being performed were part of routine care, and that data were de-identified, the IRB did not require informed consent.

**Consent to publish** The authors affirm that the human research participant provided signed consent for publication of the images in Figs. 2, 3.

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