What is the Optimal Surgical Method for Achieving Correction and Avoiding Neurological Complications in Pediatric High-grade Spondylolisthesis?

Brett Rocos, MD, FRCS (Tr & Orth), Samuel Strantzas, MSc, D.ABNM, R.EP.T, Reinhard Zeller, MD, FRCSC, Stephen Lewis, MD, FRCSC, Tony Tan, MSc, CCRP, and David Lebel, MD, PhD

Background: Controversy persists in the treatment of high-grade spondylolisthesis (HGS). Surgery is recommended in patients with intrusive symptoms and evidence debates the competing strategies. This study compares the radiologic outcomes and postoperative complications at a minimum of 2 years follow-up for patients with HGS treated with instrumented fusion with partial reduction (IFIS) with those treated with reduction, decompression, and instrumented fusion (RIF). We hypothesize that IFIS leads to a lower rate of complication and revision surgery than RIF.

Methods: A retrospective comparative methodology was used to analyze consecutive HGS treated surgically between 2006 and 2017. Patients diagnosed with $\geq$grade 3 spondylolisthesis treated with arthrodesis before the age of 18 years with a minimum of 2 years follow-up were included. Patients were excluded if surgery did not aim to achieve arthrodesis or was a revision procedure. Cases were identified through departmental and neurophysiological records.

Results: Thirty patients met the inclusion criteria. Mean follow-up was 4 years. Ten patients underwent IFIS and the remaining 20 underwent RIF. The 2 groups showed no difference in demographics, grade of slip, deformity or presenting symptoms. Of 10 treated with IFIS, the SA reduced by a mean of 10 degrees and C7 sagittal vertical line changed by 31 mm. In the RIF cohort, SA reduced by 16 degrees and C7 sagittal vertical line reduced by 26 mm. PT was unchanged in both groups. In IFIS cohort, 2 patients showed postoperative weakness, resolved by 2 years. None required revision surgery. In the RIF group, 4 sustained dural tears and 1 a laminar fracture, 7 showed postoperative weakness or dysaesthesia, 3 of which had not resolved by 2 years. Eight patients underwent unplanned further surgery, 3 for pseudarthrosis.

Conclusions: RIF and IFIS show similar radiologic outcomes. RIF shows a higher rate of unplanned return to surgery, pseudarthrosis and persisting neurological changes.

Level of Evidence Level III—retrospective comparative study.

From the Department of Orthopaedic Surgery, Hospital for Sick Children, Toronto, ON, Canada.

The authors declare no conflicts of interest.

Reprints: Brett Rocos, MD, FRCS (Tr & Orth), Hospital for Sick Children Toronto, ON, Canada M5G 1X8. E-mail: brett.rocos@sickkids.ca.

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Spondylolisthesis affects 4.4% of the pediatric population with a range of options for treatment.[1–3] Although there is a role for nonoperative care in asymptomatic patients or those with mild symptoms or low-grade spondylolisthesis, surgery is recommended for patients with pain or gait disturbance that interferes with their daily activity.[4–9] Within high-grade spondylolisthesis (HGS, Meyerding grade >2) controversy pertaining to indications for decompression, approach, reduction, interbody fusion, levels fused, and distal fixation persists.[4,10] The literature reflects this through debating the merits of surgical strategies, which include reduction of the spondylolisthesis accompanied with arthrodesis and decompression (RIF), or an instrumented fusion in situ (IFIS).[3,7,11–25]

Resolving the debate is challenging. Historically, fusion in situ has been compared with posterior, posterolateral, or combined posterior and anterior fusion, both with and without instrumentation and it has been suggested that patients obtain relief; however, fusion is achieved.[3,6,9,15,23] However, each technique brings with it the risk of complications. In 2011, Fu et al[26] showed that regardless of the surgical strategy used, the overall complication rate of HGS approaches 10.5%, with complications and postoperative neurological symptoms being present in 7.9% and 2.1% in fusion in situ and 14.4% and 10.0% in reduction and fusion, respectively. Similar figures were found by Kalanithi et al[27] in a cohort of 1225 patients treated for HGS, however, Kasliwal et al[28] used the Scoliosis Research Society morbidity database to demonstrate a complication rate of 29.1%.

At present, the evidence suggests that IFIS leads to a rate of fusion approaching 70%; however, it is associated with persisting radiologic deformity.[15,29] Regardless, Transfeldt and Mehbod[25] analyzed 5 papers comparing fusion in situ with reduction and fusion concluding that although there is a lower rate of pseudarthrosis with RIF, clinical outcomes are equivalent between the 2 techniques.[26] Similarly Freeman showed that at a mean follow-up of 12 years, patients treated with IFIS had all fused and returned to unrestricted activity

and Poussa showed that at 15 years, patients treated with IFIS showed better SRS-22 and Oswestry disability index scores than those treated with RIF.[14,30]

Nonetheless, there remains a strong argument for reduction and fusion in order to restore the normal spinopelvic relationships as suggested by Mac-Thiong and Labelle.[12,31] The outcomes of this strategy have been investigated in the past, with Crawford et al[7] showing a reduced risk of nonunion and Longo et al[32] demonstrating a lower rate of pseudarthrosis when reduction is used. Further evidence suggests that RIF improves fusion. Molinari et al[23] showed that anterior support of the instrumented levels eliminates the risk of pseudarthrosis. Unfortunately, others have found opposing evidence, showing that the technique comes at the expense of up to 50% rate of transient neurological deficit and as high as 16% rate of pseudarthrosis.[11,12,17,19,20,22,31,33–35] As yet, no long-term studies which demonstrate the long-term benefits of this technique over IFIS exists.

This study compares the radiologic outcomes and postoperative complications at a minimum of 2 years follow-up in patients treated for HGS with IFIS or RIF. We hypothesized that IFIS leads to a lower rate of neurological complications, pseudarthrosis, and revision surgeries at intermediate follow-up when compared with RIF.

METHODS

After a local research ethics board approval was granted, a retrospective comparative analysis was carried out

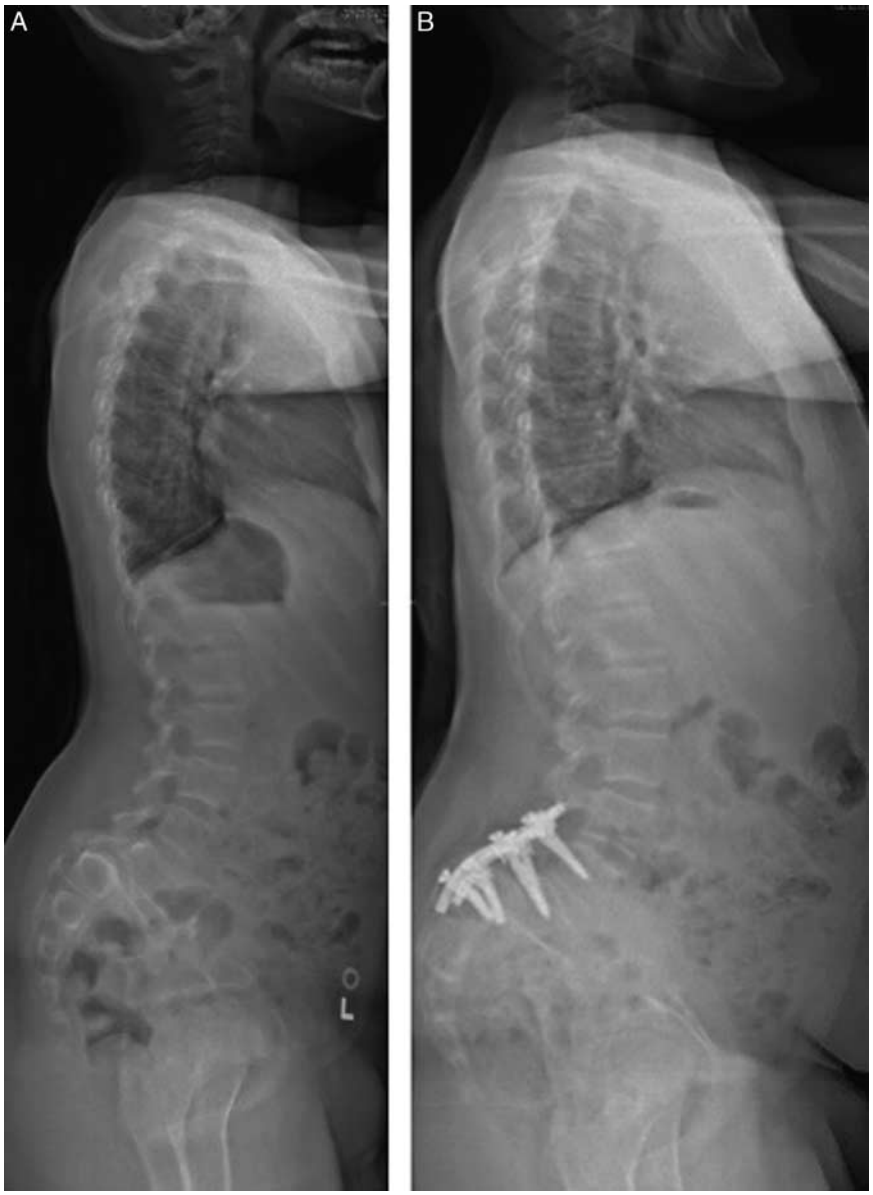

FIGURE 1. A, Preoperative lateral radiograph of L5/S1 grade 4 spondylolisthesis treated with instrumented fusion in situ (B).

on a consecutive group of patients surgically treated for HGS between October 1, 2006 and August 1, 2017. Inclusion criteria were: (i) patients diagnosed with grade 3 spondylolisthesis or more; (ii) treated with 1 of the 2 techniques described; (iii) before the age of 18 years; (iv) with a minimum of 2 years follow-up. Patients were identified through departmental and neurophysiological records. Patients were excluded if the first surgery at our unit was a revision procedure. Patients were randomly allocated to a treating surgeon as the referral was received. The operative strategy was decided by the treating surgeon.

Demographics, symptoms, examination findings, surgical plan, immediate, and delayed complications and radiographic parameters were recorded from surgical reports, outpatient and inpatient records, and radiologic investigations.

The IFIS surgical technique (Fig. 1) followed a midline approach over the lumbosacral spine and pedicle screw fixation of the L4, L5, and S1 vertebrae. No specific efforts to reduce the spondylolisthesis or slip angle beyond the reduction achieved through prone positioning of the patient or decompression was made. The rods were shaped to match the contour of the pedicle screws and sacrum, such that the distal end of the rods were buried into the sacrum distal to S1 foramina as described by Jackson and McManus.[36] The posterior elements were decorticated and overlaid with iliac crest autograft, harvested through the same incision before closure over the decorticated posterior elements.

Patients undergoing RIF (Fig. 2) were placed prone on the operating table and a midline approach to L4 posterior superior iliac spines. The L4, L5, and S1 pedicles are instrumented with pedicle screws, and the ilium with iliac screws. The L5 roots are then decompressed through a wide laminectomy and both foramina confirmed as free from neural impingement. The posterior annulus of the disk is divided and a discectomy is performed. Modified Cobb dissectors are then inserted into the disk space either side of the cauda equina and used to lever L5 into its anatomic position which is maintained through fixation of the rods

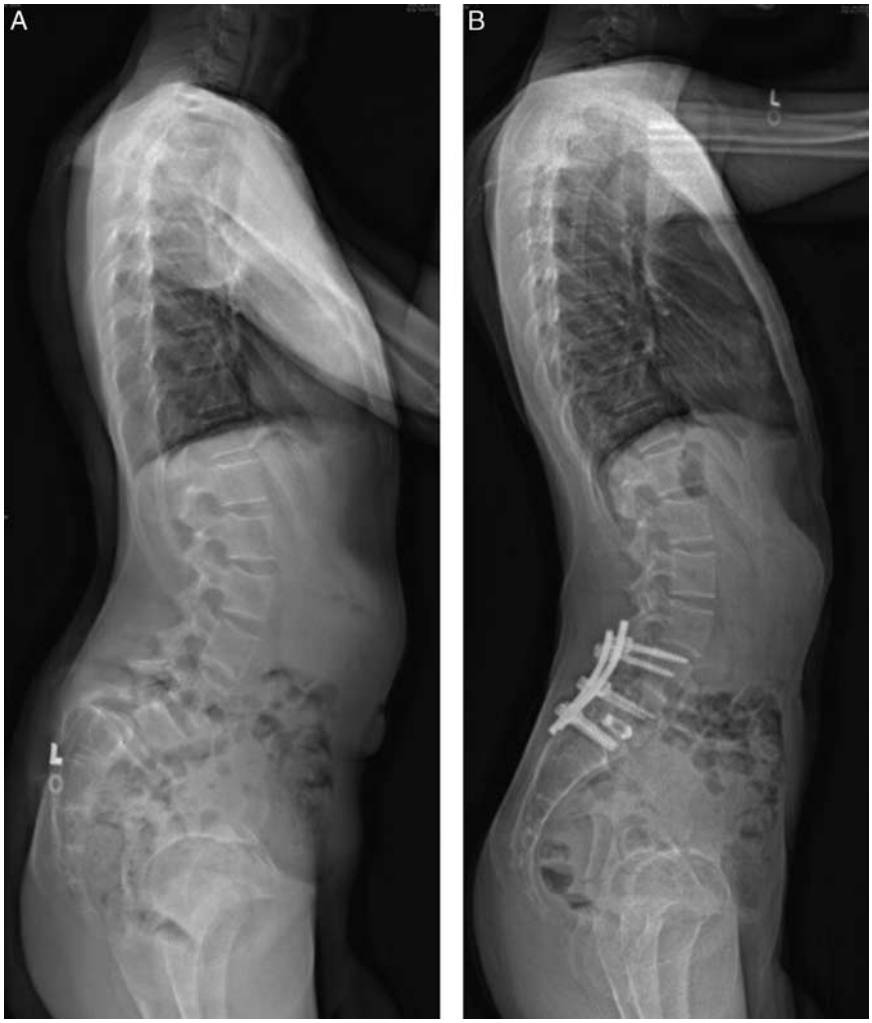

FIGURE 2. A, Preoperative lateral radiograph of L5/S1 grade 3 spondylolisthesis treated with RIF (B).

onto the previously placed pedicle screws. Reduction aimed to achieve 100% restoration of anatomic angulation and 80% correction of translation. The L5/S1 disk space is then instrumented with an interbody device filled with autograft acquired from the laminectomy. The posterior elements are decorticated and the remaining bone taken from the decompression applied to facilitate fusion before closure.

Both techniques are carried out under neuromonitoring control with motor-evoked potentials (MEPs) and somatosensory-evoked potentials (SSEPs) continuously recorded. Neither strategy used orthoses postoperatively. In patient physical therapy facilitated independent mobilization sufficient to allow patients to return home with family support. None required outpatient physical therapy for this condition. Patients were followed up at 6 weeks, 3 months, 6 months, 1 year and annually thereafter. A return to full activity was permitted at 1 year in the IFIS group and at 6 months in the RIF group.

Statistical analysis of the data was carried out using STATA versio 14.0 (StataCorp, College Station, TX). Demographics were described using assessment of central tendency and spread and each group compared using an unpaired 2 tailed *t* test where possible. Comparison of means (paired *t* test) was used to analyze the radiographic changes within each group. Categorical data were described using free text.

RESULTS

Demographics

Thirty patients met the inclusion criteria with a mean follow-up of 4.0 years (range, 2.1 to 8.8 y). Ten patients underwent IFIS and the remaining 20 underwent RIF. The radiographic parameters seen in each group at presentation are seen in Table 1. The age (mean, 14.0 y; *P*=0.8) and presenting symptoms of each group were similar with back pain and radicular pain dominating. The IFIS group showed 5 grade 3 slips, 4 grade 4 slips, and 1 grade 5 slip. The RIF group showed 12 grade 3 slips and 8 grade 4 slips. The single case of grade 5 slip was included in the study cohort as the surgical decisions and the strategy used were unchanged from those used in less severe cases, and the surgical goals were identical.

TABLE 1. The Demographics and Radiologic Parameters of Each Cohort

	RIF	IFIS	*P*
No. cases	20	10	—
Age in years (range)	14.1 (9-17)	13.9 (11.7-16.4)	0.83*
Pelvic incidence (deg.) (range)	71 (48-83)	70 (27-87)	0.83*
L5/S1 angle (deg.) (range)	16 (0-55)	11 (1-33)	0.36*
Slip angle (deg.) (range)	25 (4-58)	17 (1-41)	0.13*
Pelvic tilt (deg.) (range)	34 (14-53)	41 (20-88)	0.24*
C7-SVL (mm) (range)	50 (11-91)	67 (3-104)	0.25*
Labelle classification (n)	4(2), 5(10), 6(8)	4(3), 5(5), 6(2)	—
Meyerding grade (n)	3(12), 4(8)	3(5), 4(4), 5(1)	0.6†
Pre op sensorimotor deficits (frequency)	6	7	—

P-value represents the result of the *t* test* or Fishers exact† comparing the changes for each measurement achieved with each technique.

In the IFIS group, 3 patients showed preoperative weakness of extensor hallucis longus (EHL) affecting one or both feet. Five patients complained preoperatively of altered sensation in the lower limbs, and all patients complained of preoperative back or leg pain.

In the RIF group, 6 patients complained preoperatively of sensorimotor deficits at presentation. Five showed preoperative EHL weakness of 4/5, and 1 patient showed preoperative EHL weakness accompanied with weakness in ankle dorsiflexion. Of these, 2 showed preoperative reduced lower limb sensation. All patients complained of preoperative back and leg pain.

Radiographic Results

The changes in radiologic parameters are seen in Table 2. Neither of the techniques showed a significantly greater radiologic improvement in any parameter than the other. The individual radiographic results are seen in Table 3. The change in slip angle was equivalent in each treatment group (Fig. 3).

Neuromonitoring

Three patients showed changes in their MEPs during surgery in the IFIS group, with 9 showing changes in the RIF group. Four patients showed SSEP changes in the RIF group. Table 4 describes the changes observed, the treatment initiated and the neurological outcome in each case where changes in MEP were observed. In each case the changes were thought to be due to the reduction achieved during positioning stretching the nerve roots rather than through direct trauma or compression as a result of deliberate reduction. EMG was utilized in all cases, however, no significant, sustained activity was observed even in those cases with deficits.

Complications

In the group treated with IFIS, 2 patients showed postoperative weakness in L5 and S1 which had fully resolved by 2 years. None required revision surgery. Two further patients complained of postoperative radicular pain which was managed to resolution with oral analgesics. All patients reported an ability to carry out all activities following recovery.

In the group treated with RIF, 4 sustained dural tears and 1 a laminar fracture. Seven patients showed postoperative weakness or dysaesthesia in the L5 and S1 distribution, 3 of which had not resolved by 2 years. Neuropathic pain was reported by 6 patients, each of which was treated with oral analgesics. One of these patients required specialist pain physician care. There were no specific complaints of compromised function outside of these complications reported. Eight patients underwent unplanned further surgery, 3 for pseudarthrosis. Each patient underwent the same procedure with local autogenous bone graft and instrumentation from L4 to ilium.

The causes of unplanned revision surgery are shown in Table 5.

TABLE 2. The Changes in Radiographic Parameters Observed Following Surgery With the Associated *P*-values Derived From a Paired *t* test, and Comparison of the Radiographic Changes Seen in Each Group

	RIF			IFIS			
	Preop (95% CI)	Postop (95% CI)	Difference (95% CI, *P*-value)	Preop (95% CI)	Postop (95% CI)	Difference (95% CI, *P*-value)	Difference Between the Radiographic Changes (*P*)
Slip angle (deg.)	25 (18-31)	9 (5-13)	16 (8-24, <0.01)	17 (7-26)	7 (3-12)	10 (−0.9 to 20, 0.07)	0.304
Pelvic tilt (deg.)	34 (30-39)	34 (14-53)	0.7 (−6 to 7, 0.80)	41 (27-54)	36 (27-44)	5 (−11 to 21, 0.48)	0.510
C7-SVL (mm)	50 (35-65)	29 (15-42)	26 (9-42, <0.01)	67 (27-107)	26 (−5 to 57)	32 (−11 to 74, 0.11)	0.7120

CI indicates confidence interval; IFIS, instrumented fusion in situ; Preop, preoperative; Postop, postoperative.

DISCUSSION

Surgical treatment of patients with symptomatic HGS remains challenging. Regardless of the surgical technique selected, the literature reflects a significant complication rate.[7,8,10,37] Our data describe a similar mean improvement of slip angle in both groups and a higher incidence of postoperative surgical and neurological complications in the RIF cohort. Furthermore, it seems from these data that unplanned returns to the operating room are more common with RIF, which reflect either suspected pseudarthrosis where hardware is loose (in 1 case) or confirmed where pseudarthrosis is visible on radiology (3 cases), or other complication necessitating surgical treatment.

These analyses are supported by the results found in the literature, though the progress in spine technology and surgical strategy renders some previously published evidence less relevant in the era of posterior all pedicle screw constructs. In 1976, Wiltse and Jackson described a 100% rate of fusion using a posterolateral fusion in situ technique through a paramedian approach with iliac crest bone graft.[38] Freeman and Donati[14] showed that fusion in situ led to unrestricted activity at 12 years without any incidence of

TABLE 3. The Individual Radiographic Results

Participant ID	Surgical Strategy	Preoperative Meyerding Grade	Pelvic Incidence (deg.)	Preoperative Slip Angle (deg.)	Preoperative Pelvic Tilt (deg.)	Preoperative Sacral Slope (deg.)	Preoperative C7-SVL (mm)
1	RIF	3	79.3	7.1	13.6	66.2	27
2	RIF	3	76.7	22.2	31.3	35.9	11
3	RIF	4	66.7	40	33.7	38.5	87.3
4	RIF	3	79.8	24	43.1	39.8	91
5	RIF	3	69.9	30	53.3	13.5	11.9
6	RIF	4	67.6	58.2	31.1	40.9	45
7	RIF	3	58.9	35.2	31.3	29.7	21.5
8	IFIS	3	68.4	12.8	31.1	40.7	76
9	IFIS	3	78.3	0.7	20	58.5	6.7
10	RIF	3	65.4	32.5	45.2	19.6	46.6
11	RIF	3	78.8	9.3	36.1	45.8	21
12	RIF	4	81.9	9.6	45.8	34.3	77
13	IFIS	4	60.7	33.3	47.2	17.6	99
14	IFIS	3	27.1	4.8	87.5	55.6	95
15	RIF	3	68.9	13	23	41.3	51.5
16	IFIS	5	78.2	27.2	43	33.5	87.2
17	RIF	4	83.1	13.9	49.6	32.4	*
18	RIF	4	57.6	30.8	29.9	28	*
19	RIF	3	78.9	29.6	27.1	46.6	18.9
20	RIF	3	74.6	3.6	26.2	49.5	31.9
21	RIF	3	66.1	16.7	30.5	36.3	64.5
22	RIF	4	47.8	46.9	23.2	18.6	78.6
23	IFIS	3	75.5	40.6	36.2	38.2	103.6
24	IFIS	4	87	2.6	29.6	57.1	3.3
25	IFIS	4	68.1	16.5	30.9	40.8	*
26	RIF	3	62.9	26.2	38.3	29.5	77.6
27	RIF	4	82.8	28.1	40.6	44.7	83
28	RIF	4	76.3	21.8	33.6	42.4	*
29	IFIS	3	82.5	19.6	49.6	30.7	*
31	IFIS	4	75.8	9.3	29.7	40.3	*

*Inadequate radiographs.
C7-SVL indicates C7-sagittal vertical line.

complications in 14 patients. This was followed by Seitsalo et al,[39] who carried out a comparable analysis and showed that the highest rate of fusion was found in posterolateral fusion in situ with cancellous graft when compared with posterior fusion with periosteal grafts or anterior fusion. The study included 65 high-grade slips of which 3 showed no union to a mean follow-up of 15 years. Poussa and colleagues showed that IFIS led to improved SRS-22 scores and reduced Oswestry disability index scores over 15 years follow-up when compared with reduction and fusion, and Harris and Weinstein used a similar technique to that described here to perform 21 posterior interlaminar fusions showing that at 24 years, 20 patients were either asymptomatic or had mild symptoms, with a single incidence of pseudarthrosis.[6,30]

Over the long term, Joelson et al[40] analyzed data from 38 patients treated with fusion in situ showing that at between 28 and 41 years after surgical intervention, patients had similar pain and mental health scores when compared with control population, but that their self-image was negatively affected following surgery. In the ultra long term, Winter and Lonstein[41] showed that fusion in situ led to no functional deficits or adverse events over a 42-year follow-up, with 1 patient leading a very active life as a farm hand.

Our technique of IFIS relies on distal intrasacral rod fixation, described by Jackson and McManus.[36] We suggest that the advantage of intrasacral rods is the absence of prominent subcuticular hardware necessitating later removal, and that using this technique improves angular correction.[42] The rods may also serve to improve sacral rotation, as screws are more likely to pull out due to the generally poor quality bone in the sacrum. Within the

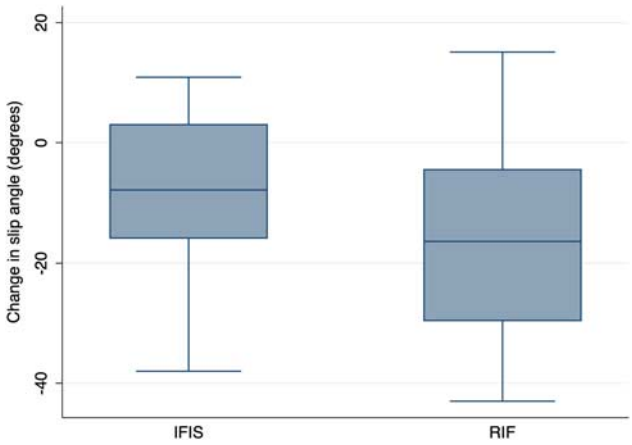

FIGURE 3. Boxplot representing the change in the slip angle measured with each surgical technique. IFIS indicates instrumented fusion in situ.

TABLE 3. *(Continued)*

Labelle Classification	Preoperative L5/S1 Angle (deg.)	Postoperative Meyerding Grade	Postoperative Slip Angle (deg.)	Postoperative Pelvic Tilt (deg.)	Postoperative Sacral Slope (deg.)	Postoperative C7-SVL (mm)
4	2.5	1	11.9	21.3	47.7	7
6	11.9	1	3.6	28.2	41.8	3
5	29.4	1	6.9	17.4	32.2	7.5
6	8.3	1	0.4	27.3	28.7	3.5
5	0.1	1	0.9	36.6	31.2	9.6
6	55.1	1	22.6	30.2	35.4	5.4
6	30.4	1	2.6	25.8	29	25.3
5	14.5	3	8.2	36.1	32.9	9.3
4	2.5	4	3.7	27.2	47	10.2
5	10.5	0	21.5	53.5	11.1	*
4	5.3	0	10.1	38.3	47.1	12
5	1.2	0	24.7	47.6	25.7	12.7
6	0.7	1	7.7	34.2	43.3	6.4
4	0.9	2	1	38.7	51.2	63.35
5	6.5	0	3.9	30.8	30.5	34.3
5	14.6	4	16	40.2	32.2	83.8
5	2.2	0	2.3	49.9	72.9	*
6	21.4	1	0.8	29.8	25.5	101
6	17.3	1	0.6	70.3	47.6	32.7
6	19.4	2	12.1	24.7	35.9	25.99
5	9.3	0	11.5	32.8	42.6	52.3
5	49.2	2	3.9	18.7	28.5	80.4
5	32.5	1	2.6	17.1	41	*
4	3.8	4	6.1	39.1	35.1	4.7
5	18.3	4	1.8	63.4	37.9	*
5	6.6	1	6.7	30.5	39.3	40.9
5	13.4	2	14	22.6	30.5	36.2
6	12.5	1	18	35.8	40.7	24.3
6	17.6	1	3.8	31	34.3	*
5	0.8	1	20.2	28.1	51.8	3

TABLE 4. The Action Taken, MEPs at Closure and Outcomes of Patients Showing Changes in MEPs During Surgery

Treatment Group	SSEP Loss	Action Taken	MEPs at Closure (% of Baseline Readings)	Postoperative Neurology (Root, MRC Grade)
IFIS	N	No action taken	50%	Right L4 4/5
IFIS	N	No action taken	50%	Normal
IFIS	N	No action taken	>90%	Left L4 4/5, left L5 4/5
RIF	Y	A	<25%	2/5 L4 bilaterally
RIF	Y	A, B, C	<10%	Bilateral L2 3/5, L3 3/5, L4 1/5, L5 1/5, S1 4/5
RIF	N	A	Normal	Left L4 3/5, Bilateral L5 4/5,
RIF	Y	B	<10%	Bilateral L4 4/5, bilateral L5 4/5
RIF	Y	No action taken	Normal	Normal
RIF	N	No action taken	<25%	Normal
RIF	N	A, B	50%	Normal
RIF	N	A	Normal	Normal
RIF	N		50%	Normal

A indicates further decompression; B, temporary removal of hardware; C, correction reduced; IFIS, instrumented fusion in situ; MEP, motor-evoked potential; SSEP, somatosensory-evoked potential.

context of spondylolisthesis, Ilharreborde and Mazda[42] showed that intrasacral rods led to reduce lumbosacral kyphosis without pseudarthrosis, neurological, or vascular complications. Bouyer investigated the same technique in 12 patients with HGS using the rods to achieve deliberate reduction describing an improvement in L5/S1 translation from 72.3% to 19% and lumbosacral tilt by 30 degrees and short-term L5 or S1 neurological deficits seen in 5 patients.[19] Lastly, Ferrero et al[22] showed that in 20 cases treated with intrasacral rods in combination with reduction and interbody fusion and sacral dome resection, a 26% reduction in translation and 34 degrees improvement in L5/S1 kyphosis was seen. The cohort showed 10 patients with transient L5 motor deficits, all of which recovered within 3 months.

Circumferential fusion has progressed with technology over recent decades. In most cases, there is little doubt that reduction leads to an improvement in spino-pelvic parameters, though this has been found not to be the case in some series.[32,43,44] Further complicating the case for reduction is that the sagittal alignment of the spine appears to be dynamic in the years following RIF.[34] Nonetheless, Molinari et al[23] presented a series of 19 patients treated with tricortical anterior graft in addition to posterior fusion, and showed no incidence of nonunion when compared with a rate of 19% in 18 patients treated with posterior fusion alone. Similarly, Fabris showed no complications or pseudarthrosis in a series of 12 patients treated with posterior instrumentation and interbody strut grafting following a mean 79% reduction by distraction, a finding supported by Crawford et al.[17,45] Helenius et al[20] showed that in a cohort of 70 patients, the 26 treated with circumferential fusion showed reduced pain, improved function, and Oswestry disability index score over a 12-year follow-up.

TABLE 5. The Causes and Frequency of Unplanned Returns to the Operating Room in Patients Treated With RIF

Reason for Unplanned Return to Operating Room	Frequency in RIF	Frequency in IFIS
Adjacent level spondylolisthesis	1	0
Bilateral limb weakness	1	0
Hardware irritation	2	0
Hardware loose	1	0
Pseudarthrosis	3	0
Repair of durotomy	1	0

IFIS indicates instrumented fusion in situ.

In this series, 12 patients showed changes in intraoperative neuromonitoring, 6 of which showed neurological complications postoperatively of which 4 resolved, demonstrating that there is an appreciable risk to neural structures regardless of the strategy used. Thuet et al[46] showed that in a cohort of 154 pediatric patients monitored during treatment of spondylolisthesis with a true positive rate of 1.9% and false negative of 2.6% which emphasizes that even with accurate intraoperative neuromonitoring, neurological complications are frequent. Careful monitoring with close interaction between surgeons and neurophysiologists remains essential in preventing neurological deficits.

Nonunion continues to be a challenge in the surgical management of HGS with 3/20 patients treated with RIF requiring revision for pseudarthrosis. In contrast, a systematic review carried out by Longo et al,[32] suggested that the rate of pseudarthrosis is higher in IFIS than in RIF (P=0.004). Another area where further work should be carried out is spondyloptosis. We have included a single case of spondyloptosis in this series, treated with IFIS, as the operative strategy used was the same as for the grade 4 cases. Nonetheless, the literature makes a distinction between spondyloptosis and spondylolisthesis, with different strategies used in managing this specific situation.[47,48] In future, there is a case to be made for analysing these separately from HGS.

The data presented in our study adds a comparable cohort to the existing literature with the benefit of medium-term follow-up and consistent surgical strategies using modern implants. This analysis is limited by the small number of cases of HGS treated surgically in the pediatric population, and consequently the small numbers in each treatment arm. What remains consistent is that the rate of unplanned return to the OR and postoperative complications with RIF concur with those published in the literature. Further study requires the collection of

prospective outcome data and identifying any further treatment that patients have received for their condition outside of the purview of our unit.

CONCLUSION

Treating pediatric HGS carries a risk of complications regardless of whether reduction and decompression is carried out in addition to fusion. Reduction, decompression, and instrumented fusion shows a higher rate of unplanned return to surgery, pseudarthrosis, and persisting neurological changes.

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