High-grade spondylolisthesis: gradual reduction using Magerl's external fixator followed by circumferential fusion technique and long-term results

Christos Karampalis · Michael Grevitt ·
Masood Shafafy · John Webb

Received: 29 December 2011 / Revised: 13 January 2012 / Accepted: 1 February 2012 / Published online: 23 February 2012
© Springer-Verlag 2012

Abstract

Purpose To report the results of a cohort of patients treated with this technique high lighting radiological and functional outcomes, discussing also benefits arising from a gradual reduction procedure compared with other techniques.

Methods We evaluated nine patients who have undergone high-grade listhesis reduction and circumferential fusion at our institution from 1988 to 2006. Average length of follow-up was 11 years (5–19). Functional outcomes and radiological measurements were recorded and reported.

Results Slip magnitude was reduced by an average of 2.9 grades (Meyerding classification). Slip angle improved by an average of 66% ($p = 0.0001$), lumbosacral angle by 47% ($p = 0.0002$), sacral rotation by 51% ($p = 0.0068$) and sacral inclination by 47% ($p = 0.0055$). At the latest follow-up 88.9% had achieved solid fusion. Post-operative 10-point Visual Analogue Score (VAS) for back pain had improved by 70% ($p < 0.001$) and that for leg pain by 76% ($p < 0.001$) compared with pre-operative score. Average postoperative Oswestry Disability Index for all patients was 8% (range 0–16%) and that for Low Back Outcome Scores was 56.6 (range 44–70). All components of Short Form 36 Health Survey were greater than 80%. Overall patients' expectations were met in 100%.

Conclusions This is an effective and safe technique which addresses the lumbosacral kyphosis and cosmetic deformity without the neurological complications which accompany other reduction and fusion techniques for high-grade spondylolisthesis.

Keywords Spondylolisthesis · Reduction · External fixator · Neurological complications

Introduction

Spondylolisthesis is the term describing forward slip of a vertebra on its caudal neighbour, initially introduced by Killian [1] in 1854 from the Greek words “σπόνδυλος” meaning vertebra and “ολισθησις” meaning slippage.

Wiltse et al. [2] described five different spondylolisthesis types according to causative factors. Furthermore, Meyerding [3] introduced a radiographic classification system measuring slip percentage. Grade I and grade II are low-grade spondylolisthesis, while grade III and grade IV are high-grade spondylolisthesis. A grade V spondylolisthesis (spondyloptosis) was later added.

Although low-grade spondylolisthesis is considered a benign spinal deformity, rarely requiring operative intervention [4], natural history of high-grade spondylolisthesis is far more complicated and surgical treatment is the preferred approach for such conditions if symptomatic [5, 6].

Much controversy exists on selection of the most appropriate operative technique [7], the main alternatives being fusion in situ or deformity reduction and fusion [8]. Although fusion in situ is the most widely accepted procedure [9] it has potential risks—pseudarthrosis, slip progression—and necessitates extended fusion to a higher normal disc level in terms of stability [8]. In order to reduce complication rates after in situ fusion, several authors proposed deformity reduction especially in patients with high-grade spondylolisthesis [10, 11].

Different reduction techniques have been reported in the past including cast reduction [10], Harrington rod distraction [11] and posterior translation through instrumented

C. Karampalis (✉) · M. Grevitt · M. Shafafy · J. Webb
Centre for Spinal Studies and Surgery, Nottingham University
Hospitals NHS Trust, Queens Medical Centre Campus,
Derby Road, Nottingham NG7 2UH, UK
e-mail: cvkorth@gmail.com

segments [12]. We describe a L5/S1 high-grade spondylolisthesis staged reduction and fixation using Magerl's external fixator and circumferential fusion reporting also the radiographic and clinical outcomes and advantages of the technique.

Materials and methods

Between 1988 and 2006, 13 patients with L5/S1 high-grade spondylolisthesis had been treated with this technique at our institution. Retrospective case note review and radiographic analysis were carried out by an observer not involved in their initial management. Information with regard to patients' demography, presenting symptoms, indication for surgery and details of the operations and complications were collected. At the latest follow-up the patients were asked to fill in pain and functional outcome score questionnaires. These included 10-point Visual Analogue Score (VAS) for pain, Oswestry Disability Index (ODI), Low Back Outcome Score (LBOS), Short Form 36 (SF-36) Health Survey and Patient Satisfaction Questionnaire.

Plain antero-posterior and lateral lumbosacral radiographs at presentation, immediately post-op and at the latest follow-up were analysed. Measurements for slip grade, slip angle, lumbosacral angle, sacral rotation and sacral inclination were made. State of fusion was also assessed. Complete set of data was available for nine patients, seven females and two males. Incomplete data set for long-term follow-up was collected for four patients and therefore omitted from analysis. Mean age at the time of operation was 16 years (range 12–22), and average length of follow-up was 11 years (range 5–19) (Table 1).

Back pain was the primary presenting complaint in 89% and leg pain in 78% of the cases. In only 56% of the cases cosmetic appearance was an issue (Table 1). One patient (case seven) had symptoms of Cauda Equina Syndrome

(Table 1). Apart from the latter patient, all had failed conservative treatment; all elected to have reduction having being counselled about other alternatives, i.e. fusion-in-situ.

Surgical technique

The procedure is carried out in three stages:

Stage 1 A wide L5/S1 posterior decompression is first carried out (Gill's Procedure) with both L5 nerve roots identified, thoroughly decompressed and traced to the tips of the L5 transverse processes. A discectomy is then performed. Standard 6 mm Schanz pins are inserted in the pedicles of L4 and iliac crests through stab incisions and Magerl's external fixator is assembled on them (Fig. 1).

Stage 2 The second stage is the gradual and progressive reduction of the slip. The Schanz pins are secured to two transverse plates of the Magerl's external fixator. The resultant frame has three longitudinal bars. Via the turnbuckle mechanism these are lengthened and shortened depending on the direction that the nuts are turned. The process starts with distraction first and later with lordosis of the instrumented segments. During this manoeuvre which is carried out twice daily, all three bars are lengthened by anticlockwise turning of their nuts. The amount of distraction is monitored by daily standing radiographs. Once enough distraction has been achieved, gradual reduction of L5 on S1 is achieved by retraction of the proximal Schanz pins on the upper transverse plate (Fig. 2). Daily radiographic monitoring continues during this process as well (Fig. 2).

The whole process is guided by patient's comfort and neurological status. Pin site care was also of paramount importance and carried out on a daily basis. Stage two on average spans over 2 weeks period. Apart from the supine posture, the frame caused no activity restrictions and patients ambulated free prior to the next stage.

Table 1 Demographic data and preoperative symptoms

Case	Age at operation (years)	Gender	Follow-up (years)	Pre operative symptoms
1	18	Female	18	Bilateral buttock pain, leg pain, S1 radiculopathy, limitation of walking distance to 1/2 mile, urgency of micturition
2	21	Female	9	Back pain, cosmesis,
3	22	Male	9	Back pain, leg pain
4	12	Female	11	Back pain, leg pain, cosmesis
5	13	Female	19	Back pain, lower limbs giving way, bilateral leg pain, paraesthesia both L5
6	12	Female	8	Back pain, leg pain, cosmesis
7	13	Female	11	Back pain, bilateral leg pain, loss of urinary control, progressive numbness, progressive weakness
8	17	Male	5	Back pain, cosmesis
9	15	Female	10	Back pain radiating to buttocks and thighs, cosmesis

Fig. 1 Magerl's external fixator applied

Stage 3 After slip reduction an anterior retroperitoneal L5/S1 fusion was performed. The hypertrophied anterior longitudinal ligament and anterior annulus were excised and a thorough discectomy carried out. A tricortical autograft or a femoral ring allograft was inserted in the disc space and held in place using 6.5 mm cortical screws and washers (Fig. 3).

If the first stage wound incision and the pin sites were clean and there was no previous bacterial growth on cultures;

the patient was then turned prone and the Magerl's external fixator and pins removed and a standard L5/S1 alar-transverse posterolateral instrumented fusion is carried out.

Results

Radiographic outcomes (Table 2).

(A) Slip grade (SG): pre operatively two cases were classified as grade V, three as grade IV and four as grade III (Meyerding classification). Immediately post-operatively, six patients were corrected to grade I and grade II. Full correction of the deformity was also achieved in two patients with grade III slip and one patient with grade IV slip. The achieved correction was maintained at the latest follow-up in all but one case. This was a grade IV slip initially corrected to grade I which finally fused as grade II.

(B) Slip angle (SA): mean preoperative SA was 67° (range 40°–93°). Immediately post-operative this had changed to a mean of 19° (range 10°–30°) with a statistically significant average correction of 72% ($p = 0.0001$). Slip angle increased to a mean of 23° (range 10°–30°) at the latest follow-up. At this point the mean percentage of correction which had dropped to 66% was still statistically significant ($p = 0.0001$).

(C) Lumbosacral angle (LSA): mean preoperative LSA was 55° (range 22°–81°). Immediately post-operative this had changed to a mean of 85° (range 68°–100°) with a statistically significant average correction of 55% ($p = 0.0001$). Lumbosacral angle decreased to a mean of 81° (range 60°–100°) at the latest follow-up. At this point the mean percentage of correction which had dropped to 47% was still statistically significant ($p = 0.002$).

(D) Sacral rotation (SR): mean preoperative SR was 43° (range 20°–78°). Immediately post-operative this had changed to a mean of 19° (range –5° to 40°) with a statistically significant average correction of 56% ($p = 0.0039$).

Fig. 2 a Preoperative X-ray. Follow-up X-ray after b distraction and after c distraction and translation

Fig. 3 **a** Preoperative X-ray. **b** Immediately postoperative X-ray. **c** Latest follow-up X-ray

Table 2 Radiographic measurements

Case	Pre-operative					Post-reduction					Latest follow-up				
	SG	SA	LSA	SR	SI	SG	SA	LSA	SR	SI	SG	SA	LSA	SR	SI
1	III	53°	72°	20°	20°	I	24°	90°	14°	30°	I	30°	84°	16°	30°
2	V	90°	36°	48°	24°	I	30°	68°	40°	32°	I	35°	60°	48°	20°
3	III	40°	81°	20°	25°	0	−10°	100°	−5°	35°	0	−10°	100°	−5°	35°
4	III	42°	70°	20°	22°	0	10°	88°	8°	28°	0	14°	86°	12°	28°
5	IV	78°	48°	72°	18°	I	23°	74°	22°	26°	II	34°	65°	28°	22°
6	IV	93°	28°	78°	10°	I	20°	72°	20°	18°	I	28°	68°	22°	20°
7	V	86°	58°	45°	12°	I	26°	88°	22°	24°	I	26°	88°	22°	24°
8	III	50°	55°	40°	10°	II	24°	98°	28°	26°	II	26°	96°	26°	26°
9	IV	74°	48°	48°	14°	0	24°	84°	24°	24°	0	24°	84°	24°	24°

SG Slip grade, SA Slip angle, LSA Lumbosacral angle, SR Sacral rotation, SI Sacral inclination

Sacral rotation increased to a mean of 21° (range −5° to 48°) at the latest follow-up. At this point the mean percentage of correction which had dropped to 51% was still statistically significant ($p = 0.0068$).

(E) Sacral inclination (SI): mean preoperative SI was 17° (range 10°–25°). Immediately post-operative this had changed to a mean of 27° (range 18°–35°) with a statistically significant average correction of 59% ($p = 0.0016$). Sacral inclination decreased to a mean of 25° (range 20°–35°) at the latest follow-up. At this point the mean percentage of correction which had dropped to 47% was still statistically significant ($p = 0.0055$).

(F) Fusion: overall eight patients had achieved radiological fusion and one patient had developed an anterior pseudarthrosis without any metalwork failure or adjacent lucencies. This was totally asymptomatic.

Pain: functional outcome scores and patient satisfaction

(A) Pain: mean preoperative VAS for leg pain was 8.4 (range 8–9) and that for back pain was 8.2 (range 6–10). At the latest follow-up they had improved to 0.8 (range 0–2) and 1.2 (range 0–2), respectively. The corresponding percentages of improvement which were 76 and 70% were statistically significant ($p < 0.001$).

(B) Functional outcome scores: ODI at the latest follow-up averaged 8% (range 0–16%). Overall 80% of the cases had no or mild disability and 20% had moderate disability. At the same time the mean LBOS was 56.6 (range 44–70). The mean SF-36 health survey for different physical domains was 87.5 (range 80–93) and that for the psychological domains was 91.25 (range 81–100).

(C) Patient satisfaction: overall seven cases scored 1 in the patient satisfaction survey score, meaning that their

expectations had been fully met and would have the surgery again under similar circumstances. In the remaining two cases, the patient satisfaction scores were two. Their expectations had been partially met but they would still choose to undergo the same surgery again.

Complications

Despite our meticulous pin site care, three cases (33%) had culture negative excessive discharge from one of their pin sites. These, however, were controlled with empirical broad spectrum antibiotics and never led to early removal of the fixator. Two patients developed transient dysaesthesia or paraesthesia relating to L5 nerve root during distraction and reduction stage. They all settled after slowing down the process. At the latest follow-up one patient had asymptomatic pseudarthrosis and one had developed a late adjacent L4/5 spondylolisthesis which was treated with extension of posterior fusion to this level.

Discussion

Natural history of high-grade spondylolisthesis is less favourable than that of low-grade slips [5, 8] and most investigators agree that surgical treatment and stabilisation is the preferred method of treating symptomatic high-grade spondylolisthesis [5, 6, 13]. Indications for surgery include slip progression, high-grade spondylolisthesis with significant lumbosacral kyphotic deformity and sagittal imbalance, neurologic deficit, low back pain unresponsive to conservative treatment, radicular pain and nerve root compression documented on imaging studies unresponsive to conservative treatment [14].

In our series indications for surgery included

1. *Chronic, persisting back pain.* Patients had limitations during daily activities without any benefit from conservative treatment. In seven of our cases leg pain was also apparent in conjunction.
2. *Neurological deficit.* Sensory deficit was recorded in two patients and combined motor and sensory loss in one patient.
3. *Severe lumbosacral kyphosis with sagittal imbalance* in seven patients.

The choice of the best surgical technique is the subject of debate [13–15] the main controversy existing between performing fusion in situ or fusion after reduction of the deformity [8]. Many authors have advocated in situ fusion without reduction for high-grade spondylolisthesis in paediatric and adult patients reporting good function and pain relief in long-term follow-up [8, 16]. On the other hand, several complications have been encountered using this

technique such as high pseudarthrosis rates (approaching 30%), progression of slippage and SA and neurological deficit development [5, 14, 17]. Furthermore proximal extension of fusion sacrifices normal motion segments. Unchanged lumbosacral kyphosis if significant, may result in sagittal imbalance and compensatory changes—thoracic hypokyphosis, lumbar hyperlordosis—to balance the trunk over the pelvis [14]. Patients tend to walk with the hips and knees flexed, have difficulty standing upright, leading to pain, fatigue and also degenerative changes proximal to the fusion level.

The main benefit of reduction of high-grade slips is correction of the lumbosacral kyphosis and improvement of the overall sagittal alignment and patient's ability to stand upright. Decreasing the SA is critical in restoring sagittal balance [5, 10]. Additionally, slip reduction—by converting shear to compressive forces—increases fusion rates preventing subsequently further progression of the deformity [14].

After reduction, the anterior column is relatively deficient and unable to withstand loads [5]. In order to improve anterior column's load-sharing ability and promote fusion rates [18], we performed circumferential fusion via combined anterior retroperitoneal approach adding in most cases structural femoral allograft in the L5/S1 disc space.

The main disadvantage of high-grade spondylolisthesis reduction is the increased risk of neurological complications ranging on different reports between 8% and almost 30% of patients [17]. Most of these deficits mainly involve L5 nerve root and are transient [19].

Cauda equina syndrome may occur even without any attempt to reduce L5 vertebra on the sacrum. Possible explanations include vascular dysfunction, temporary anterior displacement of L5 during the operation, or hyperextension with the patient on the surgical table [17].

Dural manipulations can directly injure lumbar and sacral nerve roots leading in multidermatomal deficit. Furthermore, the process of reducing L5 on S1 vertebra may displace the posterior section of the dumbbell-shaped L5–S1 disc and cause neurological dysfunction [19]. Postoperative epidural haematoma may also produce a neurological compromise by direct compression of neural elements [19].

Isolated L5 root deficits can occur due to traction applied during reduction process, decompression of the nerve or after trauma during instrumentation of the vertebrae. Delayed deficits can occur presumably on a vascular basis. When the spine is repositioned over the sacrum, the upper lumbar roots may also experience a deficit because of traction [19].

There are few reports in the literature regarding clinical application of spinal external fixation. Magerl et al. [20] described this technique as a useful temporary fixation for a traumatic spinal injury or for an infected spine [21].

External fixation of the spine was also used to estimate the effect of spinal fusion [22] or as a reduction device for scoliosis [23] or spondyloptosis [24] correction.

The main advantage of this method is that it provides the surgeon with the ability of a controlled deformity reduction while patient is awake by daily frame adjustments. Patients' neurological status is monitored as progress of reduction is evaluated with plain X-rays. Every neurological symptom is immediately recognised and adjustments can be made to reverse reduction and reduce traction applied to the neural elements. Moreover, the Magerl's external fixator allows easy restoration of lumbosacral lordosis without preceding anterior release.

In terms of biomechanical stability, external fixation device allows the correction of all three planes of spinal deformity and rigidly immobilises specific vertebral units of movement providing also enough stability for all types of loads [25]. It also enables an ambulatory programme immediately after its application [20]. Even during the distraction phase of the treatment the whole construct is sufficient for early mobilisation [23]. Stability is improved by preloading the Schanz screws, whereas secure insertion through the pedicles allows forceful reduction manoeuvres [23]. Structural elasticity of Magerl's frame adds more benefit by absorbing energy, thus protecting the Schanz screws from overload. Normally, the presence of this device is not associated with pain, unless loosening of Schanz screws happens [23].

Although having distinct benefits use of external fixation devices also has certain disadvantages. Pin sites are considered to have bacterial invasion after a time. However, in clinical experience infection along the Schanz screws has not been a problem to date. In our study three patients (33%) developed pin site discharge and had been treated with intravenous and oral antibiotics. The use of the L4 pedicles and iliac crests as fixation points does not violate the later fixation points (i.e. L5 and S1 pedicles). Schanz screw insertion through the pedicles into the vertebral body also carries some risks. Penetration into the spinal canal, injury to the prevertebral vessels and screw loosening are potential hazards in case of improper screw insertion. These complications may lead to increased pin tract drainage and premature external fixation device removal [20]. In our series all transpedicular screws were inserted under image intensifier control. There was no loosening, vascular injury or any penetration into the spinal canal.

The technique is still in use in our institution but in specific indication where significant kyphotic tilt of L4 vertebra and cosmesis concerns. Patient has also to tolerate fixator frame. After 2006 one further case was corrected using this method but was not included in the study due to insufficient follow-up. Most patients to date elect for in-situ

L4–S1 instrumented posterolateral fusion and trans-sacral fixation (Bohlmann technique).

In conclusion, staged reduction and fusion of high-grade spondylolisthesis using Magerl's external fixator restores sagittal balance and improves a severe cosmetic deformity. The main advantage of this technique is that gradual reduction under subsequent assessment of patients' neurological status allows the surgeon to detect early any neurological deterioration, reverse reduction procedure and decrease the overall incidence of dysfunction of neural elements.

Conflict of interest No benefits or funds in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Kilian H (1854) Schilderungen neuer Beckenformen und ihres Verhaltens im Leben. Verlag Von Bosserman, Mannheim
2. Wiltse LL, Newman PH, Macnab I (1976) Classification of spondylolisthesis and spondylolisthesis. Clin Orthop 117:23–29
3. Meyerding H (1932) Spondylolisthesis: surgical treatment and results. Surg Gynecol Obstet 54:371–377
4. Beutler WJ, Fredrickson BE, Murtland A et al (2003) The natural history of spondylolysis and spondylolisthesis: 45-year follow-up evaluation. Spine 28:1027–1035 (discussion 1035)
5. Boxall D, Bradford DS, Winter RB et al (1979) Management of severe spondylolisthesis in children and adolescents. J Bone Joint Surg Am 61:479–495
6. Bunnell W (1982) Back pain in children. Orthop Clin North Am 13:587–604
7. Edwards CC, Bradford DS (1994) Controversies: instrumented reduction of spondylolisthesis. Spine 19:1535–1536
8. Transfeldt EE, Mehbood AA (2007) Evidence-based medicine analysis of isthmic spondylolisthesis treatment including reduction versus fusion in situ for high-grade slips. Spine 32(19):S126–S129
9. Verbiest H (1979) The treatment of lumbar spondyloptosis or impending lumbar spondyloptosis accompanied by neurologic deficit and/or neurogenic intermittent claudication. Spine 4:68–77
10. Bradford DS (1979) Treatment of severe spondylolisthesis: a combined approach for reduction and stabilization. Spine 4: 423–429
11. Harrington PR, Tullos HS (1971) Spondylolisthesis in children: observations and surgical treatment. Clin Orthop 79:75–84
12. Curcin A, Edwards CC (1994) Reduction and fusion of spondyloptosis: long-term follow-up. Presented at the Scoliosis Research Society Annual Meeting Sept 21–24 Portland
13. Mehdian SM, Arun R, Jones A et al (2005) Reduction of severe adolescent isthmic spondylolisthesis: a new technique. Spine (Phila Pa 1976) 30(19):E579–E584
14. Agabegi SS, Fischgrund JS (2010) Contemporary management of isthmic spondylolisthesis: pediatric and adult. Spine J 10(6):530–543
15. Lenke LG, Bridwell KH (2003) Evaluation and surgical treatment of high-grade isthmic dysplastic spondylolisthesis. Instr Course Lect 52:525–532
16. Frennered AK, Danielson BI, Nachemson AL et al (1991) Mid-term follow-up of young patients fused in situ for spondylolisthesis. Spine 16:409–416

17. Schoenecker PL, Cole HO, Herring JA et al (1990) Cauda equina syndrome after in situ arthrodesis for severe spondylolisthesis at the lumbosacral junction. *J Bone Joint Surg Am* 72:369–377
18. Molinari RW, Bridwell KH, Lenke LG et al (2002) Anterior column support in surgery for high-grade, isthmic spondylolisthesis. *Clin Orthop* 394:109–120
19. Ogilvie JW (2005) Complications in spondylolisthesis surgery. *Spine (Phila Pa 1976)* 30(6):S97–S101
20. Magerl FP (1984) Stabilization of the lower thoracic and lumbar spine with external skeletal fixation. *Clin Orthop Relat Res* 189: 125–141
21. Jeanneret B, Magerl F (1994) Treatment of osteomyelitis of the spine using percutaneous suction/irrigation and percutaneous external spinal fixation. *J Spinal Disord* 7(3):185–205
22. Esses SI, Botsford DJ, Kostuik JP (1989) The role of external spinal skeletal fixation in the assessment of low-back disorders. *Spine* 14:594–601
23. Reyes-Sánchez A, Rosales LM, Miramontes V (2005) External fixation for dynamic correction of severe scoliosis. *Spine J* 5(4):418–426
24. Doita M, Uno K, Maeno K et al (2008) Two-stage decompression, reduction, and interbody fusion for lumbosacral spondylolisthesis through a posterior approach using Ilizarov external fixation. *J Neurosurg Spine* 8(2):186–192
25. Kuniyoshi A, Manohar M, Panjabi J et al (1989) Biomechanical evaluation of spinal fixation devices. Part III. Stability provided by six spinal fixation devices and interbody bone graft. *Spine* 14:1249–1255