Eur Spine J
DOI 10.1007/s00586-017-4976-z

GRAND ROUNDS

Circumferential fusion for degenerative lumbar spondylolisthesis complicated by distal junctional grade 4 spondylolisthesis in the sub-acute post-operative setting

Alexander A. Theologis[1] · Deeptee Jain[1] · Christopher P. Ames[2] · Murat Pekmezci[1]

Received: 9 October 2016 / Revised: 13 December 2016 / Accepted: 23 January 2017
© Springer-Verlag Berlin Heidelberg 2017

Abstract

Introduction Surgical management for lumbar stenosis is generally safe and provides significant improvements in pain, disability, and function. Successful lumbar decompression hinges on removing an appropriate amount of lamina and other compressive pathology in the lateral recess. Too little bony decompression can result in persistent pain and disability, while over resection of the pars and/or facets may jeopardize spinal stability.
Case report In this unique report, we present for the first time an acute iatrogenic grade 4 L5–S1 spondylolisthesis distal to a L3–5 laminectomy and circumferential instrumented fusion due to bilateral iatrogenic L5 pars fractures and its management and clinical outcomes after revision operation. The patient presented with worsening pain, neurologic compromise, and severe sagittal imbalance. The iatrogenic, high-grade spondylolisthesis was urgently addressed with a L5–S1 anterior lumbar interbody fusion and extension of posterior instrumentation to the pelvis, which resulted in considerable pain relief, resolution of neurologic deficits, and reconstitution of acceptable sagittal imbalance.
Conclusion All attempts during a lumbar decompression should be made to prevent iatrogenic pars fractures, as they may result in severe sagittal imbalance, neurologic compromise, and persistent disability. Iatrogenic, high-grade L5–S1 spondylolisthesis can be successfully treated with reduction using circumferential fusion of the lumbosacral junction.

Keywords Lumbar stenosis · Laminectomy · Pars fracture · High-grade spondylolisthesis · Health-related quality of life scores

Case presentation

A 59-year-old female with a history of morbid obesity (BMI 49.1), insulin-dependent type 2 diabetes mellitus, hypertension, depression, and chronic pain presented to the outpatient setting of a community spine surgeon in 2014 with low back pain and neurogenic claudication. Her pain was debilitating, persistent, and progressive despite several epidural steroid injections, physical therapy, and a multimodal pain regimen that included MS Contin 30 mg BID, Oxycodone, Neurontin 600 mg QID, and Lyrica 100 mg TID. Initial radiographs demonstrated degenerative lumbar stenosis and spondylolisthesis at L3–4 and L4–5 (Fig. 1).

✉ Alexander A. Theologis
Alekos.Theologis@ucsf.edu

[1] Department of Orthopaedic Surgery, University of California-San Francisco (UCSF), 500 Parnassus Avenue, MU West 3rd Floor, San Francisco, CA 94143, USA

[2] Department of Neurologic Surgery, UCSF, San Francisco, CA, USA

Published online: 15 February 2017

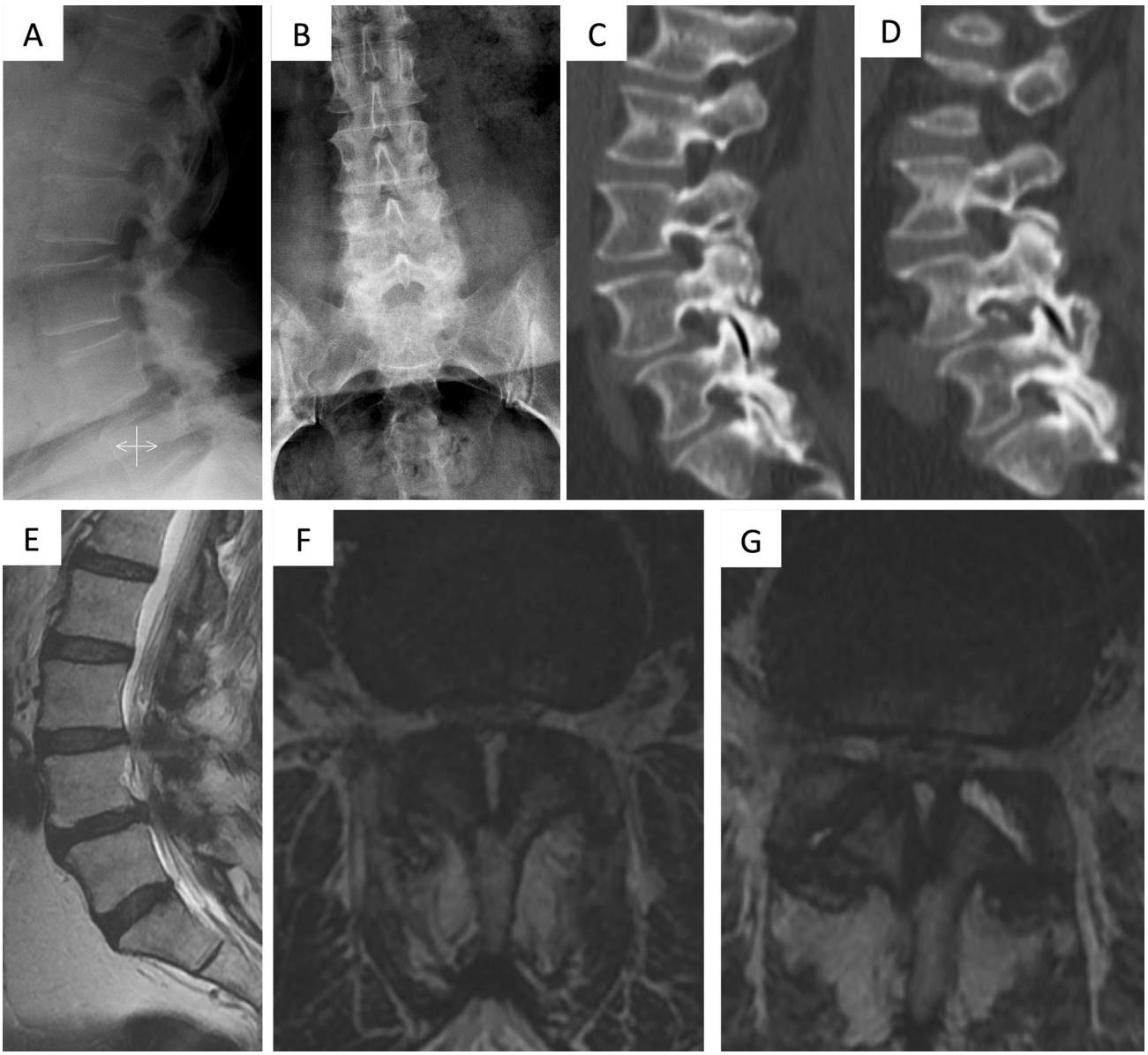

Fig. 1 Pre-operative radiographs (**a**, **b**) demonstrating L3–4 and L4–5 grade 1 degenerative spondylolisthesis. Note the overstress on the L5 pars by the L4 inferior facet joints. No pars fractures were identified bilaterally on pre-operative CT scans (**c**, **d**). However, the L5–S1 disc height was similar to the more proximal levels and there is L5–S1 facet joint arthritis (**c**, **d**). Severe central stenosis at L3–4 (**f**) and L4–5 (**g**) was evident on pre-operative magnetic resonance imaging (**e**)

Severe central stenosis from L3 to L5 was evident on MRI and there were no pars defects on CT scan (Fig. 1). To address her neurologic symptoms, laminectomies (inferior 3/4 of L3, entire L4, and superior 1/3 of L5) and bilateral L3–4 and L4–5 facetectomies with L3–5 transforaminal lumbar interbody fusions and posterolateral spinal fusion were performed. No L5–S1 foraminotomies were performed. Intra-operatively, there were no reported complications, and the acute post-operative period was uneventful. However, 2 weeks post-operatively, the patient reported worsening back and bilateral leg pain, which was then followed 2 weeks thereafter by bilateral leg weakness, numbness, and difficulty walking. Radiographs demonstrated distal junctional grade 4 spondylolisthesis at L5–S1 with bilateral pars fractures (Fig. 2). She was subsequently transferred to a tertiary care center for further evaluation and management. On presentation to our hospital, she had 3–4 out of 5 strength in her bilateral lower extremities, decreased sensation over the anterior thighs, legs, and feet, intact rectal tone, and normal perianal sensation. A full-length standing spine radiograph demonstrated severe global sagittal imbalance [PI: 60°; LL: 50°; PI-LL: 10°; PT: 25°; slip angle: −3° (kyphosis); SVA: 14.3 cm] (Fig. 2).

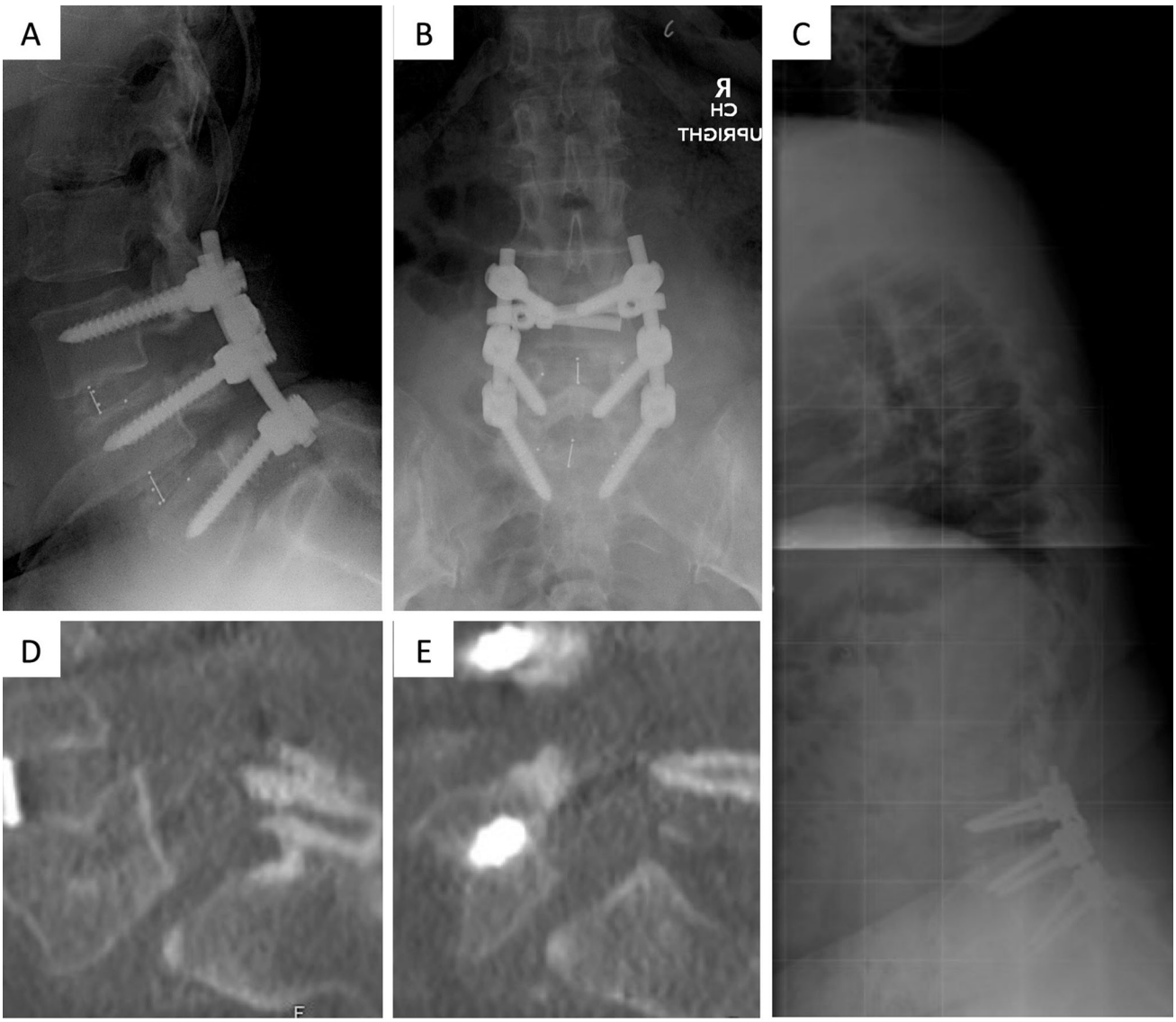

Fig. 2 Post-operative radiographs (**a**, **b**) 4 weeks after the index L3–5 laminectomy, L3–5 posterior instrumentation and transforaminal lumbar interbody fusions demonstrated a distal junctional grade 4 spondylolisthesis at L5–S1. Note the relatively low position of the L5 screws, the heads of which may have impinged on the L5 isthmus. While hardware was intact, bilateral L5 pars fractures were identified on CT scan (**d**, **e**). This resulted in severe sagittal imbalance [pelvic incidence (PI): 60°; lumbar lordosis (LL): 50°; PI-LL: 10°; pelvic tilt: 25°; slip angle: −3° (kyphosis); sagittal vertical axis: 14.3 cm]

Diagnostic imaging

Historical review of the condition, epidemiology, diagnosis, pathology, differential diagnosis

Lumbar spinal stenosis is a major source of pain and disability that affects a large portion of the population. While operative intervention has consistently been shown to provide meaningful and lasting pain relief and improvement of general health and function for patients with spinal stenosis, decompression of neural elements is not free of complications [1–5]. A successful decompression hinges on removing an appropriate amount of lamina and other compressive pathology in the lateral recess. Too little bony decompression can result in persistent pain and disability, while over resection of the pars and/or facets may jeopardize spinal stability. The degree of instability depends on the extent of facet and pars resection [6–8]. Although wide lumbar facet joint destruction will not produce acute instability [6], disruption of the lateral or true pars can, as evidenced by our case. As such, it is recommended that the lateral pars be exposed to determine its width and care be taken when resecting the superior edge of the distal vertebra's lamina so as to avoid over resection when performing a lumbar laminectomy. The risk for iatrogenic pars fractures is higher in the lower lumbar spine than the upper

lumbar spine due to variations in pars' anatomy [9]. Ebraheim et al. demonstrated that the isthmus is thinner and longer in lower lumbar levels, which leaves them vulnerable to lysis [10]. Additionally, Weiner et al. found that the lateral buttresses (bony arches connecting and dampening loads between the pars and pedicle—two perpendicular structures) at L1, L2, and L3 are broad and nearly identical in size while their sizes at L4 and L5 are 40 and 80% smaller than the upper levels, respectively [9]. Furthermore, in a previous biomechanical study by Wiley et al, a 5 mm residual bridge of pars at L2 was found to be quite strong, whereas a 7 mm residual pars bridge at L5 was weak and susceptible to fracture [9]. In addition to the amount of bone resected, Brunet et al. hypothesize that devascularization of the pars during its subperiosteal dissection may weaken it in the face of compressive and tensile forces [11]. While the exact amount of bone resected and the residual width of the pars after decompression in our patient cannot be quantified, the development of bilateral L5 pars fractures within several weeks of the operation were likely a result of her severe obesity and an overaggressive bony resection of the cranial aspect of L5 lamina that jeopardized the integrity of the L5 pars, which may have already been relatively thin due to her small stature. Additionally, other pre-operative and post-operative factors may have contributed to this acute failure at the L5 pars. First, the pre-operative radiographs and CT demonstrate that the L5 pars already had an overstress by the inferior facet joints of L4 (Fig. 1). Secondly, the pre-operative CT scan demonstrated that the L5–S1 disc height was similar to the more proximal levels and there was L5–S1 facet joint arthritis (Fig. 1). In the setting of the patient's low back pain, the initial surgeon could have performed L5–S1 facet joint injections to assess whether that level was a possible pain source. If it were an important location of pain, then not having included L5–S1 in the posterior instrumented fusion during the initial operation may have been an underestimation. Additionally, pre-operative full-length standing spine radiographs were not obtained. If they were available pre-operatively, the full sagittal profile may have been accounted for during the index operation. After the fact, we see that the patient had an important thoracic kyphosis with an anterior SVA, as demonstrated on the post-operative radiographs (Fig. 2), which resulted in compensatory hyperlordosis with posterior overload and anterolisthesis. After the operation, this hyperlordosis also overstressed the pars and may have been compounded by additional stress on the thinner L5 pars from impingement by the heads of the L5 screws that were positioned relatively low in the pedicles (Fig. 2). Accounting for all these pre-operative radiographic nuances during the index operation may have prevented the failure.

Rationale for treatment and evidence-based literature

While the development of a high-grade lumbar spondylolisthesis distal to a previous lumbar fusion has not previously been reported, high-grade L5–S1 spondylolisthesis is a topic of much discussion and debate. Neurologic compromise, lumbosacral kyphosis, and significant sagittal imbalance are hallmarks of high-grade isthmic spondylolisthesis and have been correlated with a compromise of health-related quality of life scores [12–16]. As such, the goal of surgical management is local deformity correction to improve regional and global sagittal alignment, pain control, resolution of neurological symptoms, and a long-term stable fusion. While the surgical treatment of high-grade lumbar spondylolisthesis remains controversial and can be accomplished via numerous anterior- and posterior-based techniques (fusion in situ, posterior decompression and posterolateral instrumented fusion with or without reduction and interbody fusion [17–20], we chose to address the deformity with a circumferential fusion through an anterior L5–S1 anterior lumbar interbody fusion (ALIF) and posterior decompression with extension of the instrumentation to the pelvis with the goals of reduction of the spondylolisthesis, neurologic decompression, and improvement of regional and global sagittal alignment.

Procedure

She was taken urgently to the operating room for deformity correction and stabilization via a circumferential fusion. The operation began with an anterior retroperitoneal approach performed by a vascular surgeon. Pre-operative neuromonitoring showed a 30% decrease in motor-evoked potentials. After a standard L5–S1 discectomy, serial T-handle distraction was used to re-establish alignment. This was followed by placement of an appropriately sized interbody cage (14 × 27 mm; 14° lordosis). The ALIF cage was first fixed to the S1 body with a blade, which allowed anterior translation of the sacrum, while a posterior directed force was applied on the L5 body via a bone graft impactor. When adequate reduction was achieved, the cephalad blade was inserted into the L5 body to maintain the reduction. Reduction to grade 1 spondylolisthesis was accomplished with this technique. The patient was then turned prone and the previous instrumentation was removed and replaced with new instrumentation (reduction pedicle screws placed at L4) that extended to the pelvis/ilium (Fig. 3). The remaining L5 lamina (inferior 2/3) was removed and wide L5–S1 foraminotomies were performed; the L5 nerve roots were intact. Rods were placed dorsally from L3 to the pelvis. No further reduction was able to be

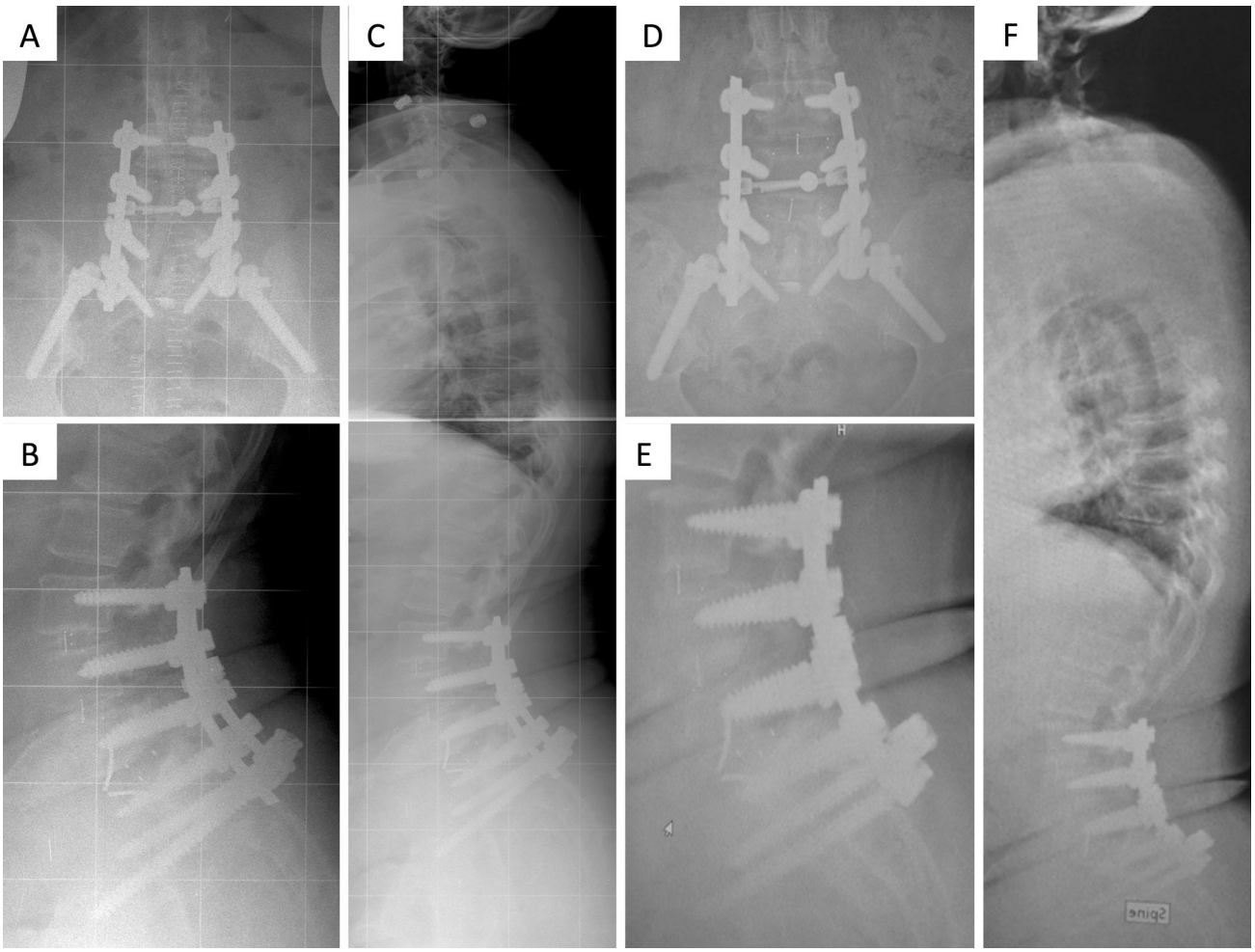

Fig. 3 Post-operative radiographs after undergoing a L5–S1 anterior lumbar interbody fusion, L5 laminectomy, and extension of instrumented fusion to the pelvis demonstrated reduction of the L5–S1 spondylolisthesis to grade 1 and excellent restoration of regional and sagittal alignment [pelvic incidence (PI): 58°; lumbar lordosis (LL): 65°; PI-LL: 7°; pelvic tilt (PT): 17°; slip angle: +25° (lordosis); sagittal vertical axis (SVA): 4.1 cm] (**a**–**c**). At final follow-up at 15 months, hardware was intact with no evidence of loosening and excellent sagittal alignment was maintained (PI: 59°; LL: 56°; PI-LL: 3°; PT: 15°; slip angle: 21° (lordosis); SVA: 4.5 cm)

achieved. Estimated blood loss was 400 cc. Neuromonitoring signals at the end of the operation were stable.

Procedure imaging

Outcome, follow-up

Post-operatively, she was admitted to the floor where her neurologic examination was noted to be improved—sensation was diminished only in the left foot and strength was full in the right leg except for 3 out of 5 strength of the extensor halluces longus (EHL). The left leg had persistent 4-/4 out of 5 strength in the proximal muscle groups and 3 out of 5 strength in the distal muscle groups (tibialis anterior, EHL, gastrocnemius). On post-operative day 4, she ambulated with a walker with physical/occupational therapy. Post-operative standing radiographs demonstrated reduction of the L5–S1 spondylolisthesis to grade 1 and excellent restoration of lumbopelvic and global sagittal alignment [PI: 58°; LL: 65°; PI-LL: 7°; PT: 17°; slip angle: +25° (lordosis); SVA: 4.1 cm] (Fig. 3). She was discharged to an acute rehabilitation facility on post-operative day 7 in stable condition.

Subsequent post-operative appointments were performed by her original surgeon. Health-related quality of life scores post-operatively are presented in Table 1. In follow-up, she was noted to have a full improvement in neurologic function and a significant decrease in narcotic usage. At 6-month follow-up, she had full strength and sensation in the lower extremities and was walking with a cane. She had mild–moderate low back pain (VAS back 6) that was controlled with three tablets of Norco 5/325 mg per day; there was no buttock or leg pain. She was no

Table 1 Health-related quality of life outcome scores

	Post-operative time			
	6 Weeks	3 Months	6 Months	15 Months
VAS back pain	2	4	6	5
ODI	0	55	67	67
SF-36				
MCS	40.1	21.2	32.5	21.1
PCS	24.2	30.8	34.5	25.2
NDI	14	62	72	40

VAS visual analog scale, *ODI* Oswestry Disability Index, *SF* Short-Form, *MCS* mental component scale, *PCS* physical component scale, *NDI* Neck Disability Index

longer taking MS Contin, Oxycodone, Gabapentin, or Lyrica. However, she was tearful at every encounter and reported severe disability [Oswestry Disability Index score (ODI 67); Neck Disability Index (NDI 72), and poor general health [Short-Form 36 (SF-36) Physic Component Score (PCS; 34.5); Mental Component Score (MCS; 32.5)].

Fifteen months post-operatively, she was noted to be doing "quite well" in the office, although general health scores (SF-36 MCS 21.1; PCS 25.2) had worsened and disability related to her low back and neck remained severe (ODI 67, NDI 40). Radiographs demonstrated intact hardware and maintenance of good sagittal alignment [PI: 59°; LL: 56°; PI-LL: 3°; PT: 15°; slip angle: 21° (lordosis); SVA: 4.5 cm] (Fig. 3). She remained off MS Conti and Oxycodone, her neurologic examination was normal, and she was walking with no assistive devices. This was considered an excellent outcome. As such, her report of persistent disability and poor general HRQoL scores suggest that the perceived benefit of the surgery may be influenced by other factors that have been shown to negatively impact surgical outcomes (i.e., chronic pain, depression) [21–28] or may represent her preoperative general state of health.

Compliance with ethical standards

Conflict of interest Dr. Ames is a consultant for Stryker, Medtronic, and Depuy. He has a patent with Fish & Richardson, P.C. He receives royalties from Stryker and Biomet Spine. Dr. Pekmezci has received a grant from Nuvasive unrelated to this study. Dr. Theologis has received a grant from Depuy-Synthes unrelated to this stuy. He and the remaining authors have no other conflicts of interest or financial ties.

References

1. Weinstein JN, Tosteson TD, Lurie JD et al (2010) Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the Spine Patient Outcomes Research Trial. Spine (Phila Pa 1976) 35:1329–1338
2. Weinstein JN, Lurie JD, Tosteson TD et al (2007) Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. N Engl J Med 356:2257–2270
3. Weinstein JN, Lurie JD, Tosteson TD et al (2009) Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis. Four-year results in the Spine Patient Outcomes Research Trial (SPORT) randomized and observational cohorts. J Bone Jt Surg Am 91:1295–1304
4. Rihn J, Hilibrand A, Zhao W et al (2015) Effectiveness of surgery for lumbar stenosis and degenerative spondylolisthesis in the octogenarian population: analysis of the Spine Patient Outcomes Research Trial (SPORT) data. J Bone Jt Surg Am 97:177–185
5. Ghogawala Z, Dziura J, Butler W et al (2016) Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. N Engl J Med 374:1424–1434
6. Haher TR, O'Brien M, Dryer JW et al (1994) The role of the lumbar facet joints in spinal stability. Identification of alternative paths of loading. Spine (Phila Pa 1976) 19:2667–2670 **(discussion 2671)**
7. Lee KK, Teo EC (2004) Effects of laminectomy and facetectomy on the stability of the lumbar motion segment. Med Eng Phys 26:183–192
8. Zander T, Rohlmann A, Klöckner C, Bergmann G (2003) Influence of graded facetectomy and laminectomy on spinal biomechanics. Eur Spine J 12:427–434
9. Weiner BK, Walker M, Wiley W, McCulloch JA (2002) The lateral buttress: an anatomic feature of the lumbar pars interarticularis. Spine (Phila Pa 1976) 27:E385–E387
10. Ebraheim NA, Lu J, Hao Y et al (1997) Anatomic considerations of the lumbar isthmus. Spine (Phila Pa 1976) 22:941–945
11. Brunet J, Wiley J (1984) Acquired spondylolysis after spinal fusion. J Bone Jt Surg Br 66:720–724
12. Harroud A, Labelle H, Joncas J, Mac-Thiong JM (2013) Global sagittal alignment and health-related quality of life in lumbosacral spondylolisthesis. Eur Spine J 22:849–856
13. Tanguay F, Labelle H, Wang Z et al (2012) Clinical significance of lumbosacral kyphosis in adolescent spondylolisthesis. Spine (Phila Pa 1976) 37:304–308
14. Tanguay F, Mac-Thiong JM, Wang Z et al (2010) Developmental spondylolisthesis: is slip angle related to quality of life? Stud Health Technol Inform 158:182–185
15. Labelle H, Roussouly P, Berthonnaud E et al (2005) The importance of spino-pelvic balance in L5–S1 developmental spondylolisthesis: a review of pertinent radiologic measurements. Spine (Phila Pa 1976) 30:S27–S34
16. Hresko MT, Labelle H, Roussouly P, Berthonnaud E (2007) Classification of high-grade spondylolistheses based on pelvic version and spine balance. Spine (Phila Pa 1976) 32:2208–2213
17. Boachie-Adjei O, Do T, Rawlins BA (2002) Partial lumbosacral kyphosis reduction, decompression, and posterior lumbosacral transfixation in high-grade isthmic spondylolisthesis: clinical and radiographic results in six patients. Spine (Phila Pa 1976) 27:E161–E168
18. Bradford DS, Boachie-Adjei O (1990) Treatment of severe spondylolisthesis by anterior and posterior reduction and stabilization. A long-term follow-up study. J Bone Jt Surg Am 72:1060–1066
19. Poussa M, Remes V, Lamberg T et al (2006) Treatment of severe spondylolisthesis in adolescence with reduction or fusion in situ: long-term clinical, radiologic, and functional outcome. Spine (Phila Pa 1976) 31:583–590 **(discussion 591–2)**
20. Smith J, Deviren V, Berven S et al (2001) Clinical outcome of trans-sacral interbody fusion after partial reduction for high-grade L5–S1 spondylolisthesis. Spine (Phila Pa 1976) 26:2227–2234
21. Smith JS, Shaffrey CI, Glassman SD et al (2013) Clinical and radiographic parameters that distinguish between the best and worst outcomes of scoliosis surgery for adults. Eur Spine J 22:402–410

22. Abtahi A, Brodke D, Lawrence B et al (2015) Association between patient-reported measures of psychological distress and patient satisfaction scores after spine surgery. J Bone Jt Surg Am 97:824–828
23. Adogwa O, Parker SL, Shau DN et al (2012) Preoperative Zung Depression Scale predicts outcome after revision lumbar surgery for adjacent segment disease, recurrent stenosis, and pseudarthrosis. Spine J 12:179–185
24. Daubs MD, Norvell DC, McGuire R et al (2011) Fusion versus nonoperative care for chronic low back pain: do psychological factors affect outcomes? Spine (Phila Pa 1976) 36:S96–S109
25. Miller JA, Derakhshan A, Lubelski D et al (2015) The impact of preoperative depression on quality of life outcomes after lumbar surgery. Spine J 15:58–64
26. Alvin MD, Miller JA, Sundar S et al (2015) The impact of preoperative depression on quality of life outcomes after posterior cervical fusion. Spine J 15:79–85
27. Anderson JT, Haas AR, Percy R et al (2015) Clinical depression is a strong predictor of poor lumbar fusion outcomes among workers' compensation subjects. Spine (Phila Pa 1976) 40:748–756
28. Vialle E, de Oliveira Pinto BM, Vialle LR, Gomez JDC (2015) Evaluation of psychosomatic distress and its influence in the outcomes of lumbar fusion procedures for degenerative disorders of the spine. Eur J Orthop Surg Traumatol 25 (Suppl 1):S25–S28