Revision Strategies for Harrington Rod Instrumentation: Radiographic Outcomes and Complications

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Abstract

Study Design: Retrospective case series.

Objective: The purpose of this study is to evaluate the clinical and radiographic outcomes following revision surgery following Harrington rod instrumentation.

Methods: Patients who underwent revision surgery with a minimum of 1-year follow-up for flatback syndrome following Harrington rod instrumentation for adolescent idiopathic scoliosis were identified from a multicenter dataset. Baseline demographics and intraoperative information were obtained. Preoperative, initial postoperative, and most recent spinopelvic parameters were compared. Postoperative complications and reoperations were subsequently evaluated.

Results: A total of 41 patients met the inclusion criteria with an average follow-up of 27.7 months. Overall, 14 patients (34.1%) underwent a combined anterior-posterior fusion, and 27 (65.9%) underwent an osteotomy for correction. Preoperatively, the most common lower instrumented vertebra (LIV) was at L3 and L4 (61%), whereas 85% had a LIV to the pelvis after revision. The mean preoperative pelvic incidence–lumbar lordosis mismatch and C7 sagittal vertical axis were 23.7° and 89.6 mm. This was corrected to 8.1° and 28.9 mm and maintained to 9.04° and 34.4 mm at latest follow-up. Complications included deep wound infection (12.2%), durotomy (14.6%), implant related failures (14.6%), and temporary neurologic deficits (22.0%). Eight patients underwent further revision surgery at an average of 7.4 months after initial revision.

Conclusions: There are multiple surgical techniques to address symptomatic flatback syndrome in patients with previous Harrington rod instrumentation for adolescent idiopathic scoliosis. At an average of 27.7 months follow-up, pelvic incidence–lumbar lordosis mismatch and C7 sagittal vertical axis can be successfully corrected and maintained. However, complication and reoperation rates remain high.

Keywords

harrington rod instrumentation, revision surgery, adult spinal deformity, adjacent segment degeneration

Introduction

From the early 1960s until the early 1980s, Harrington rod instrumentation (HRI) was considered the standard of care for the surgical management of idiopathic scoliosis (IS). Early and long-term outcome studies revealed excellent correction and maintenance of coronal deformity.1-5 With HRI, distraction instrumentation allowed for greater correction and maintenance in the coronal plane, but the combination of a straight
rod and distractive forces caused a loss of lumbar lordosis with subsequent anterior translation of the vertical axis and the body’s center of gravity. The patient attempts to compensate locally by hypextending any segments not included in the instrumentation as well as the cervical spine and by pelvic retroversion and flexing knees in order to stand upright or to maintain horizontal gaze. Lordosis was observed to decrease retroversion and flexing knees in order to stand upright or to instrumentation as well as the cervical spine and by pelvic locally by hyperextending any segments not included in the corrective technique of flat back syndrome has been well described, often requiring a concomitant osteotomy. However, the increase in lordosis below the fusion cannot always compensate for the overall loss of lordosis in the fused portion of the spine. The progressive positive sagittal malalignment and subsequent symptoms that develop has been termed “flatback syndrome.”

The progressive sagittal malalignment with concurrent back and leg pain can necessitate revision surgical intervention. The corrective technique of flatback syndrome has been well described, often requiring a concomitant osteotomy. However, revision surgery in the setting of prior Harrington rod instrumentation presents with unique challenges due to the presence of a prior fusion mass obscuring anatomic landmarks for pedicle screw instrumentation, significant defects in the iliac wing making iliac fixation challenging at times in addition to the quandary of deciding if the entirety of the prior instrumentation needs to be removed, or if parts can be retained.

There are some small case reports on outcomes following revision of patients that only underwent Harrington rod constructs for IS; however, no formal case series or comparison of surgical techniques for revision in this specific patient population have been described in the literature. The purpose of this study is to evaluate the clinical and radiographic outcomes after revision surgery for flatback syndrome following HRI.

Methods and Materials

Patients who underwent revision spine surgery in the setting of HRI for IS were evaluated from 5 participating research sites in the United States that are enrolled into a prospective, multicenter ASD (adult spinal deformity) database and a separate series from an additional tertiary academic hospital from January 2012 to August 2018. Of note, all 6 sites received institutional review board approval prior to enrolling patients. All patients were older than 18 years with inclusion criteria that they had previously undergone another revision spine surgery or that the treating surgeon. Patients were excluded from the study if they had previously undergone another revision spine surgery after HRI. Demographic data collected included age, sex, body mass index, and American Society of Anesthesiologists (ASA) physical status score.

Data collection in terms of surgical strategy included approach (posterior, anterior, or both), performance of a 3-column osteotomy, and biologic adjunct. Perioperatively, the length of hospital stay, estimated blood loss, and operative time were obtained for all procedures. Preoperative and postoperative standing posteroanterior and lateral full-length radiographs of the spine were evaluated by 2 observers. Spinal measurements were performed using the SpineView software (ENSAM ParisTech) preoperatively, at 6 weeks postoperative, and 1-year postoperative intervals measuring lumbar lordosis (LL), pelvic incidence (PI), PI-LL mismatch, PT, sacral slope (SS), C7-S1 SVA, and TK. The Oswestry Disability Index (ODI) scores were obtained preoperatively, at 6 weeks postoperative, and 1-year postoperative intervals. Complications were recorded, which included infection, dural tear, implant-related, cardiopulmonary, or neurologic. Any subsequent reoperations were recorded as well.

Description of the preoperative information, including demographic data, ASA grade, location of previous posterior fusion and preoperative alignment were performed using mean and standard deviation for continuous variables and rate for categorical variables. Postoperative outcomes were also investigated. Change in radiographic alignment between pre- and postoperative visits was performed using repeated measure with Bonferroni adjustment for multiple comparison. Statistical analysis was performed using SPSS 20.0 and \( P < .05 \) was considered statistically significant.

Results

A total of 41 patients with a mean age of 55.7 ± 8.6 years (range 32-74 years) were studied with an average follow-up of 27.7 months (12-121 months). In total, the mean ASA score was 2.2 ± 0.6 (61% had an ASA score of 2, and 24% had an ASA score of 3+) and 36 patients (87.8%) were female. Mean body mass index for the cohort was 29.1 ± 6.9 kg/m². Preoperative upper instrumented vertebra (UIV) levels and lower instrumented vertebra (LIV) levels as well as the postoperative LIV of the revision surgery are presented in Figure 1. Of the 41 patients that were included in the study, 32 patients underwent surgery for iatrogenic-related flatback, whereas 9 patients underwent surgery for adjacent segment degenerative pathology. Prior to the revision surgery, the most common LIV was at L3 and L4 (61%), and 60% of the patient had an UIV located between T3 and T5.

Preoperative alignment demonstrated a moderate sagittal malalignment according to Scoliosis Research Society (SRS)–Schwab classification with 72.5% of the patient with PT modifier at + or ++, 80.0% with PI-LL modifier at + or ++, and 77.5% with SVA modifier at + or ++.

Overall, 14 patients (34.1%) underwent a combined anterior-posterior (AP) fusion and 27 (65.9%) underwent an osteotomy for correction (Table 1). Bone morphogenetic protein (BMP) was used in 31 (73%) cases. Mean estimated blood loss (EBL) was 2000 ± 1240 mL, while mean operative time varied greatly (802 ± 731 minutes). All patients underwent a posterior fusion. Five patients underwent a proximal extension (mean number level extended 4.4 ± 1.5) and 100% of the patients underwent a distal extension (2.7 ± 1.3 level, ranging from 1 to 6), with 85.4% instrumented to the ilium. The
hospital stay averaged 7.8 ± 3.2 days (median 7 days) following surgery.

Postoperative radiographic outcomes are shown in Table 2. Preoperatively, the mean PI-LL mismatch was 23.8° (−13.0° to 61.9°) and the mean C7-SVA was 89.6 mm (−45.5 to 313.0 mm). This was corrected to 8.1° and 28.9 mm and maintained to 9.04° and 34.4 mm at latest follow-up. On average, ODI scores were 40.6 ± 17.7 preoperatively and improved to 23.5 ± 21.1 at 1-year follow-up.

The overall complication rate was 61%. Complications included deep wound infection (12.2%), durotomy (14.6%), implant related failures (14.6%), and temporary neurologic deficits (22.0%) (Table 3). Eight patients (19.5%) underwent further revision surgery at an average of 7.4 months after the initial revision. Four patients that underwent an all-posterior revision surgery experienced pseudarthrosis at L4-5 and/or L5-S1, one of which included bilateral rod fractures. All 4 patients underwent anterior lumbar interbody fusions at the pseudarthrosis levels. Two patients that underwent combined anterior-posterior approaches, with a caudal level of fusion at L4 in 1 patient and L5 in the second patient, experienced debilitating symptoms related to adjacent segment degeneration (1 at L4-5 and 1 at L5-S1, respectively). Both underwent anterior lumbar interbody fusion procedures at the adjacent level with extension of the posterior instrumentation. Last, 2 patients experienced lower extremity radicular symptoms that required revision open posterior decompressions.
When comparing patients undergoing a combined AP versus an all-posterior approach, there were no significant differences in the demographics, length of hospitalization, or operative time. However, the AP fusion group did experience great EBL compared to the all-posterior group (P = .010). Radiographically, apart from preoperative TK (post 37.9° ± 16.9°, AP 27.8° ± 11.4°; P = .031) and SVA (post 67.9° ± 63.2 mm, AP 129.9° ± 95.8 mm; P = .042), there were no significant differences between the preoperative, 6-week postoperative, and 1-year postoperative radiographic parameters (Table 4). When evaluating ODI scores, there were no differences between the 2 groups at preoperative (post 45.8° ± 16.9, AP 50.0° ± 17.3) and 1-year postoperative (post 27.2 ± 19.9, AP 31.1 ± 17.6) time points. Similarly, there was no significant difference in complication (post 63.0% vs AP 64.4%) and reoperation (25.9% vs 7.1%) rates between the 2 groups.

### Discussion

This study represents the largest case series examining revision strategies and outcomes following revision for adjacent segment degeneration and flatback syndrome following HRI. In a series of 41 patients, we show that treatment of HRI can successfully correct PI-LL mismatch and C7-SVA. However, complication and reoperation rates remain relatively high. Our strategies here can outline successful techniques to achieve improved radiographic and clinical outcomes.

Although flatback syndrome is a widely recognized complication following HRI, many patients also presented to the clinic with leg pain in the setting of adjacent segment degeneration. The overall effects of a long segment fusion can drastically affect the load, function, and motion within the caudal adjacent segments as well as the metabolism of the disc and facet cartilage at the motion segments adjacent to the fusions.16,17 Literature supports changes in the adjacent level biomechanics,
but no causal relationship has been firmly attributed with degeneration. One potential source for the biomechanical changes is altered sagittal alignment after arthrodesis (such as HRI), and this has been implicated to increase the rate of adjacent segment disease.18-20 As most patients undergoing HRI for idiopathic scoliosis were young, degeneration in the unfused segments below the instrumented vertebra should be considered if they present with progressively worsening low back and leg pain.

The back and leg pain associated with the progressive sagittal alignment can be debilitating to the point of requiring surgical intervention. Dangers and complications in these cases are related to the subverted anatomy of the spine due to the huge amount of bone fusion. The goal of corrective surgery in the treatment of flatback syndrome is to restore physiologic lordosis and sagittal balance such that the sagittal vertical axis intersects the posterior aspect of the sacrum. Obtaining the necessary correction to achieve sagittal balance allows the patient to stand and walk with their hips and knees in a physiologic posture, improves overall body function, and reduces fatigue-associated back and neck pain.9,21 The literature has described a direct association between PI, LL, and health-related quality of life outcomes.22,23 Concurrently, based on the data previously discussed by Lafage et al,24 the threshold for which adults experience disability with sagittal alignment (SVA, PI-LL, and PT) increases with age. A variety of osteotomies and interbody fusion techniques are utilized to directly increase lordosis, especially in the setting of flatback syndrome. In this study, 27 of the 41 patients (66%) underwent an osteotomy for correction. Of those, 16 patients (40%) underwent a Smith-Petersen osteotomy (SPO), while 10 patients (24%) underwent a pedicle subtraction osteotomy (PSO; Figure 2). No vertebral column resections (VCRs) were performed. Single- or multilevel SPOs were performed at levels with mobile discs. Surgeons performed a PSO in the setting of more rigid deformities in which more focal lordosis correction was necessary. As with this report, studies that have looked at revision surgery for flatback syndrome (with diverse previous instrumentation or in native spines) show excellent correction and maintenance of the PI-LL mismatch and C7-SVA (Figure 3).6,8,9,11,25,26 In this series, the flexibility of the flatback deformity also dictated the use of dual approaches. In the setting of a mobile disc spaces (previously unfused segment) at L4-L5 and/or L5-S1 the placement of hyperlordotic anterior lumbar interbody fusion grafts has been shown to also generate significant LL at the L4-S1 segments.27-29 However, the approaches used and osteotomies performed were ultimately based on the pre-operative plan and judgment of the treating surgeon.

To date, there are no case series that describe the outcomes following revision of patients that underwent HRI for adolescent idiopathic scoliosis. However, there are some isolated case
reports that describe outcomes in this patient population aside from case series that describe flatback syndrome revision surgery due to various presentations and previous hardware techniques. Hedlund et al.\(^\text{30}\) described a case report on a patient that presented with flatback syndrome 38 years after undergoing HRI for adolescent IS. Following a L3 PSO, standing radiographs showed a restoration of lordosis by 35° and restoration of C7 plumb line to +2 cm; maintained at 6 months following surgery.\(^\text{30}\) Marino et al.\(^\text{14}\) described 2 patients who presented with adjacent segment degeneration at L4-5 following Harrington rod placement 28 and 40 years ago. One underwent a combined anterior-posterior approach, and the other underwent a posterior-only decompression and fusion with successful correction and maintenance of the sagittal parameters 18 months following these revisions. Similarly, Liu et al.\(^\text{15}\) presented 3 cases of Harrington rod revisions for flatback syndrome that underwent various surgical approaches and osteotomies to obtain successful correction and maintenance of sagittal plane correction. The patients included in this study experienced similar mean operative times (802 ± 731 minutes) and EBL (2000 ± 1240 mL) as described in these case reports. However, no post-operative complications were described in those case reports following revision of previous HRI. In our study, 26 of 41 (63.4%) patients suffered a complication, including deep wound infection (12.2%), durotomy (14.6%), implant-related failures (14.6%), and temporary neurologic deficits (22.0%), while 8 patients (19.5%) underwent further revision surgery (Figure 4). The complication and reoperation rates are similar to other studies that describe revision surgery for flatback syndrome. Glassman et al.\(^\text{31}\) described a perioperative complication rate of 62% in revision spine surgery performed after previous operations for scoliosis. Similarly, Bridwell et al.\(^\text{11}\) described 14 early complications and 6 late complications in 27 patients that underwent a PSO for fixed sagittal imbalance. Overall, complication rates range from 25% to 72% and include pseudarthrosis, rod fracture, venous thromboembolism, myocardial infarction, infection, injury to major blood vessels, neurological injury, stroke, pneumonia, arrhythmia, and even death.\(^\text{6,8,32,33}\)

As proximal junctional kyphosis or adjacent segment pathology cephalad to previous HRI is not common, if the previous fusion is solid and the rod is well fixed to the spine (often bone has grown over the rod itself, the HRI can be left in place with the new construct tied to the previous instrumentation. This frequent lack of proximal pathology is important because the revision surgery can also be performed with a more limited approach that does not require exposure of the entire previous HRI. Thus, we recommend maintaining the previous instrumentation (if well fixed and the previous fusion is solid) and performing a limited exposure as these techniques may reduce intraoperative blood loss and operative time, which are known to affect complication rates postoperatively. In our

![Figure 3](https://example.com/figure3.jpg)
limited cohort, reoperation rates in the all-posterior revision group was high (7 patients, 26%). In addition, 6 patients underwent a revision, posterior, instrumented fusion short of the sacrum and pelvis and 2 (33%) required a reoperation to extend the construct to the pelvis within 1 year. Given this, we would recommend posterior instrumentation extended to the sacrum and pelvis with interbody placement. Additionally, we would not hesitate to use an anterior approach for interbody placement if that technique is within the surgeon’s skill set.

There are limitations in this study, including the small size of the cohort, which limit our ability to provide comparative analysis between the impact of different surgical approaches and techniques. However, these cases are the largest series to date focused solely on revision surgery for flatback syndrome in the setting of previous HRI for IS in a multicenter setting. As several surgeons in multiple centers were included in this study, the indications and technique of the various revision surgeries were based on the judgment and experience of the surgeons, thus no formal protocols dictated the specific surgical intervention. However, given this multicenter experience, we feel that the results are more representative to the general population. Additionally, our minimum follow-up is only 12 months, so other late complications or reoperations may present outside of this follow-up time frame. With an average follow-up of 27.7 months, we feel that we have adequately captured many of the early radiographic and clinical outcomes, most likely are underreporting pseudarthrosis and rod fracture in cases with only 12 months of follow-up.

Conclusion
There are multiple surgical techniques to address symptomatic flatback syndrome in patients with previous Harrington rod instrumentation for adolescent idiopathic scoliosis. In a multicenter retrospective review of 41 patients with an average of 27.7 months follow-up, PI-LL mismatch and C7 sagittal vertical axis can be successfully corrected. However, complication and reoperation rates remain high.

Declaration of Conflicting Interests
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