Published in final edited form as:

Spine (Phila Pa 1976). 2014 July 1; 39(15): 1211–1216. doi:10.1097/BRS.0000000000000375.

Complications and Outcomes of Complex Spine Reconstructions in Poliomyelitis-Associated Spinal Deformities: A Single Institution Experience

Jakub Godzik, BA¹, Lawrence G. Lenke, MD¹, Terrence Holekamp, MD, PhD², Brenda Sides, BS¹, and Michael P. Kelly, MD^{1,†}

¹Department of Orthopaedic Surgery, Washington University in St Louis, School of Medicine

²Department of Neurological Surgery, Washington University in St Louis, School of Medicine

Abstract

Study Design—Retrospective case-series

Objective—Share our institutional experience with spinal reconstruction for deformity correction in patients with a history of poliomyelitis.

Background Data—Polio and post-polio syndrome are not uncommonly related to a paralytic spinal deformity. Limited modern data exists regarding outcomes and complications following spinal reconstruction in this population.

Methods—A clinical database was reviewed for patients undergoing spinal reconstruction for polio-associated spinal deformity at our institution from 1985 to 2012. Relevant demographic, medical, surgical and postoperative information were collected from medical records and analyzed. Preoperative and last follow-up SRS-22 scores were recorded.

Results—A total of 22 patients with polio who underwent surgical deformity correction were identified. Mean age was 49 years (Range, 12–74), and 15 patients (68%) were female. Preoperative motor deficit was present in 14/22 (64%). All patients underwent instrumented spinal fusion (Mean 13 vertebral levels, Range, 3–18). Ten (10/22, 45%) patients developed major complications, and four patients (4/22, 18%) developed new postoperative neurological deficits. Neurological monitoring yielded a 13% false negative rate. At 2-year follow-up (20/22), patients maintained an average coronal correction of 25 degrees (33%, $p = 0.001$) and sagittal correction of 25 degrees (34%, $p = 0.003$). Minimum 2-year follow-up data were available for 11/22 (50%) of patients. At an average of 72 months of follow-up (Range, 28 – 134 months), the mean SRS22 pain subscore improved from a mean of 2.75 to 3.6 ($p = 0.012$); self-image from 2.8 to 3.7 ($p = 0.041$); function from 3.1 to 3.8 ($p = 0.036$); satisfaction from 2.1 to 3.9 ($p = 0.08$); mental health from 3.7 to 4.5 ($p = 0.115$).

Conclusion—Spine reconstruction for poliomyelitis-associated deformity was associated with high complication rates (54%) and sometimes unreliable neurologic monitoring data. Despite this,

[†]**Corresponding Author and Address:** Michael P. Kelly, MD Assistant Professor, Department of Orthopaedic Surgery, Washington University School of Medicine 660 South Euclid Avenue, Campus Box 8233, St Louis, Missouri 63110 kellymi@wudosis.wustl.edu Tel: (314) 747-2535; Fax: (314) 747-2599.

patients undergoing spine reconstructions had significantly improved outcomes scores. These data may help surgeons appropriately counsel this complicated patient population.

Keywords

post-polio syndrome; poliomyelitis; spinal deformity

INTRODUCTION

Polio is an acute, viral infection caused by poliovirus. In a subset of patients, poliovirus enters the central nervous system and preferentially targets the anterior horn cells of the spinal cord causing poliomyelitis. Resulting manifestations include muscle weakness and flaccid paralysis, leading to progressive poliomyelitis-associated spinal deformity (PD) in nearly 30% of patients.¹ Despite effective vaccination and near eradication of new poliovirus infections worldwide, chronic poliomyelitis remains the most prevalent motor neuron disease in the United States.² A recent survey identified approximately 1.6 million patients living with poliomyelitis in the United States and nearly 20 million worldwide.^{2,3}

Between 22 to 64% of polio infection survivors are at risk of developing late manifestations of poliomyelitis in their lifetime.^{2,4,5} The resulting post-polio syndrome (PPS) presents with new or progressive muscle weakness, and worsening of existing musculoskeletal conditions, particularly scoliosis. In many instances, patients fail conservative therapy and ultimately require surgical intervention.^{3,6}

Some have suggested an increased operative risk in polio and PPS due to the underlying spinal cord injury stemming from initial infection as well as increased metabolic demand of surviving motor-neurons.⁷⁻¹⁰ Despite advances in surgical technique, there are limited modern reports on the clinical outcomes of scoliosis surgery in polio patients.¹¹ Given the rate of PPS and the number of survivors worldwide, it is critical to understand the unique challenges involved in the surgical care of polio and post-polio patients from a modern perspective.

The purpose of this study was to review our experience with spinal reconstruction for deformity correction in patients with paralytic scoliosis secondary to poliomyelitis, and to determine the (1) prevalence of perioperative and follow-up complications; (2) amount of coronal and sagittal correction achieved; (3) long-term clinical outcomes using the Scoliosis Research Society-22 instrument.

MATERIALS AND METHODS

After Institutional Review Board approval, patients who had undergone spinal reconstructive surgery for poliomyelitis-associated spinal deformity (PD) were identified in the operative database between 1985 and 2012 at a single institution. Inclusion criteria for the study were a documented history of polio infection or post-polio syndrome, diagnosis of spinal deformity (scoliosis or kyphoscoliosis), and spinal surgery by one of two fellowship trained, spinal deformity surgeons. Patients with a history of spinal trauma, tumor, or connective tissue diseases were excluded.

Patient data were obtained from clinic notes, operative summaries, and hospital records. When available, the history of polio infection and surgical management was recorded, including age of initial spinal fusion and number of past procedures. Surgical data for the index surgery included fusion type (anterior, posterior, combined), staging (single-stage, multi-staged), use of spinal osteotomy (e.g. posterior column osteotomy (i.e. Smith Peterson, Ponte)[PCO], pedicle subtraction osteotomy [PSO], or vertebral column resection [VCR]), levels of instrumentation, estimated blood loss (liters), and operative time (hours).

Complications were classified as minor and major by the criteria of Glassman *et al.*,¹² and further differentiated as neurological or non-neurological. Revision surgery was defined as any subsequent, unplanned spine surgery. We assessed for statistical associations between a variety of patient and procedural characteristics and the risk of operative/postoperative complications.

Preoperative and postoperative 2-year radiographs were reviewed by a fellowship trained, spinal deformity surgeon. Standard radiographic measurements were obtained using 36 inch and lateral upright radiographs, including Cobb angles for major coronal and sagittal curves, coronal and sagittal balance by C7 plumb lines, and pelvic parameters (sacral slope, pelvic incidence).

All available intraoperative monitoring data were collected from an institutional neurological monitoring database. Monitoring modalities included somatosensory-evoked potentials (SSEP), motor-evoked potentials (NMEP), descending neurogenic evoked potentials (DNEP), triggered electromyography (T-EMG), and spontaneous electromyography (S-EMG). False negative was defined as a new postoperative neurological deficit without a corresponding change in neurological monitoring data.

Preoperative and postoperative health-related quality-of-life measures, as assessed by the Scoliosis Research Society-22 Questionnaire (SRS-22), were compared. Patients who had missing preoperative or less than 2-year minimum postoperative evaluations were excluded from this analysis.

Statistical Analyses

Analysis of continuous and dichotomous variables was conducted using the Mann-Whitney and Fisher's exact test, respectively. Bivariate analysis of paired data was completed using Wilcoxon signed rank test of non-parametric data. All analyses were performed using SPSS v.19 (SPSS, Chicago, IL, USA). Statistical significance threshold was set at $p < 0.05$.

RESULTS

Twenty-two patients with a history of poliomyelitis underwent reconstruction of a spinal deformity at our institution from 1985 to 2012 (Table 1). Average follow-up was 82 months (range 7 months to 134 months). Minimum 2-year postoperative follow-up data were available for 20/22 (mean, 7.5 years; range, 2.8 to 13.8). The mean age was 49 (range, 12 to 74), consisting of 15 females and 7 males. Poliovirus infection occurred at a mean age of 7 (Range, 2 to 13). Fourteen patients (14/22, 64%) demonstrated residual lower extremity

weakness from poliomyelitis. Twelve patients (54%) had undergone prior spinal surgery, six of whom had undergone multiple prior procedures. The indications for revision were primarily curve progression (7/12), but also included pseudarthrosis (4/12), and pain (1/12).

All patients underwent posterior spinal fusion (PSF) with instrumentation (Table 1), eleven of whom (11/22, 50%) underwent additional anterior spinal fusion (ASF). The average number of levels fused was 13 (Range 3 to 18), with 5/22 patients undergoing sacropelvic fixation (Table 1). PCOs were performed in 10 patients, over an average of three levels (Range, 1 to 7 levels). PCOs were performed more frequently in the revision setting than in primary deformities (67% vs. 40% $p = 0.043$). The mean surgery duration was 9 ± 3 hours (Range, 6 to 15 hours), with a mean EBL of 1.6 ± 0.8 Liters (Range, 0.5 to 2.7 Liters).

Complications

The overall complication rate was 54% (12/22) with a 45% incidence of major complications. New neurological deficits (4/22, 18%) and pseudarthrosis (4/22, 18%) were the most common complications. Two patients suffered complicated post-operative courses with prolonged ICU stays [1 fever of unknown origin; 1 re-intubation]. Remaining complications included deep surgical site infection (1/22), removal of iliac implants (1/22), and revision surgery for curve progression (1/22).

Complications were associated with older age (Mean: 58 years, Range 41 to 67 [complication] vs. 39, Range 12 to 62 [no complication], $p = 0.028$), and revision surgery (OR 7, 95%CI: 1.1 to 46, $p = 0.084$). Preoperative neurologic status (OR 3, 95%CI: 0.5 to 18.2, $p = 0.378$), fusion length (13 levels vs. 11, $p = 0.314$), and duration of surgery (8.9 hrs vs. 8.2, $p = 0.798$) were not related to the occurrence of a complication. Major complications were associated with older age (59 vs. 41, $p = 0.023$), and revision surgery (OR 8, 95%CI: 1.1 to 56, $p = 0.043$). There were seven (7/22, 32%) unplanned reoperations (3 pseudarthrosis; 2 neurological deficit; 1 symptomatic instrumentation; 1 curve progression). Reoperations were more common in patients undergoing PCOs during the index procedure (OR 16.5, 95% CI 1.5 to 183, $p = 0.020$).

There were 4/22 (18%) new or worsened postoperative neurologic deficits. Three patients (13%) developed postoperative lower extremity weakness in a specific nerve root distribution identified in the immediate postoperative period. One patient (5%) suffered postoperative paraplegia, which developed within 12 hours following surgery. Preoperatively, this patient had severe kyphoscoliosis (Combined Cobb: 223 degrees) with severe motor weakness in both lower extremities (3/5 Motor Scores). A new postoperative neurological deficit was associated with older age (58 vs. 48, $p = 0.049$), use of osteotomy (OR 1.7, $p = 0.029$), and greater blood loss (2.2 vs. 1.1 Liters, $p = 0.045$); neurological deficits were not associated with revision surgery (31% vs. 0%, $p = 0.115$), preoperative neurological deficit (29% vs. 0%, $p = 0.29$), longer fusion length (13.5 vs. 12, $p = 0.52$), and longer operative time (10.4 vs. 8 hours, $p = 0.243$).

Radiographic Data

Radiographic results are reported in Table 2. The mean preoperative coronal Cobb decreased from 73 degrees (range 21 to 133) to 49 degrees (range 0 to 110) at 2-year follow up (mean 33% correction, $p=0.001$). Mean thoracic kyphosis decreased from 59 degrees (range 21 to 92) preoperatively to 35 degrees (range 0 to 70, $p=0.003$). The mean correction in coronal alignment was 27 mm ($p = 0.061$) and the mean change in sagittal alignment was 50 mm ($p = 0.002$). One patient had worsening of their coronal C7 plumb line more than 10 mm (from -15 to 38 mm).

Intraoperative Monitoring

Eighteen patients (18/22, 82%) had intraoperative monitoring performed during scoliosis surgery; SSEP monitoring alone was performed in 1/18, and 17/18 had multimodality monitoring. Sixteen patients had monitoring modalities capable of detecting injury to ventral and dorsal columns, as baseline lower extremity DNEP signal was absent in one patient.¹³ Two patients developed neurological deficits (False negative 2/16, 13%).¹³ Of the 4 patients without monitoring, none developed postoperative neurological deficits.

Outcomes

SRS-22 scores were available at the preoperative and postoperative visit for 11 non-consecutive patients (11/22, 50%) at an average follow-up time of 72 months (range 28–134 months). Statistically significant differences were observed in three SRS-22 subscales (Table 3): pain +0.86(Pre: 2.75, Post: 3.6, $p=0.012$), self-image +0.87(Pre: 2.8, Post: 3.7, $p=0.041$) and patient function +0.67(Pre: 3.1, Post: 3.8, $p=0.036$).

DISCUSSION

There has been little written regarding the safety and effectiveness of spinal reconstructive surgery for polio-associated spinal deformity.^{7,9,10} Poliomyelitis and the resulting flaccid paralysis may predispose patients to surgical complications, particularly increased blood loss and respiratory complications.⁸ The current study describes a single institution experience treating polio-associated spinal deformities over a 27-year period. In our experience, patients with poliomyelitis possess a higher risk of complications than surgical correction of idiopathic deformities. Despite these risks, clinical improvements in radiographic measurements and outcomes scores are possible.

In our series, we found a 45% incidence of major complication following spinal fusion in patients with poliomyelitis-associated spinal deformity with an average follow-up of 6 years. In particular, the 18% incidence rate of new neurological deficits in our cohort was dramatically higher than in past reports of either poliomyelitis patients or adult revision surgeries.¹⁴ Three patients suffered permanent nerve root deficits, and one patient developed paraplegia. Notably, neurological deficits occurred without corresponding reduction in signal amplitude in appropriate monitoring modalities in two cases (2/16, 13%).

Previous studies of scoliosis surgery in poliomyelitis report lower rates of neurological deficits, ranging from 1% to 8%.^{7,9,10} In 1981, Leong et al.⁹ reported a series of 110 patients

undergoing primary deformity correction. Despite an overall complication rate of 74%, the incidence of perioperative neurological deficits was only 5% compared to the 18% observed in the current study. Both in Leong et al.⁹ and Mayer et al.,¹⁰ neurological deficits were transient in nature and attributed to patient positioning and pre-operative cervical traction.⁹ While Eberle et al.⁷ did not describe the rate of neurological deficit, nearly 40% of patients suffered a reduction in ambulatory status. In contrast, the neurological deficits reported here remained permanent, however, with limited impact on ambulatory status.

The 18% incidence of neurological deficit observed in the current study is significantly higher than reported in modern studies of scoliosis surgery for adult and adolescent idiopathic scoliosis. In 2011, Hamilton et al.¹⁵ reported a 1.84% neurological complication rate in scoliosis surgery in over 100,000 patients from the Scoliosis Research Society Morbidity and Mortality database. Similarly, a review of both revision and primary surgeries for adult idiopathic scoliosis at our institution found only 11 (6%) new postoperative neurological deficits in 250 patients.¹⁴ Thus it is likely that scoliosis surgery in polio patients poses a higher risk of neurological injury than in patients with AIS. This increased risk may be related to the damage incurred by anterior horn cells from poliomyelitis, as well as the secondary chronic effects of overuse and inflammatory stress in the pool of surviving motor neurons. While clear experimental evidence in this regard is lacking, we hypothesize that the increased metabolic demand of surviving motor neurons may render these cells more susceptible to ischemia, portending a greater risk of delayed postoperative neurological deficit or exacerbation of pre-existing neurological deficit.

Despite the high sensitivity of multimodality monitoring for detecting neurological injury, the shortcomings of neural monitoring in patients with pre-existing neurological conditions are well known.^{16,17} Several cases of false-negatives have been previously reported in patients with anterior tract deficits.^{18,19} Studies suggest the increased metabolic rate of surviving motor neurons in polio may alter the susceptibility of motor neurons to anesthesia,^{3,8,16} as described by Gyermek et al.,²⁰ in which the recovery time and ED50 of several muscle relaxants (pancuronium, gallamine, tubocurarine) were compared between 30 pediatric patients with a history of polio infection and a 51-subject control group. The authors reported a significantly lower therapeutic threshold in the polio cohort, attributing this to increased receptor sensitivity and density.²⁰ Although no direct experimental data confirms the impact of such altered sensitivity on neural monitoring in polio patients, Owen et al.¹⁶ described the differential effects of anesthetic agents on SEP monitoring in neuromuscular patients undergoing spinal surgery, with decreased signal amplitude and prolonged signal latency.

Surgeons should be aware of the reduced effectiveness of monitoring and higher rate of neurological deficit associated with spinal deformity surgery in patients with a history of poliomyelitis. Given underlying the limited functional reserve in this population, we believe careful neurological assessment both preoperatively and immediately following surgery are crucial to appreciate minor changes in motor function. Stagnara wakeup tests should be rehearsed, to facilitate an accurate examination if needed during surgery. Past studies have also emphasized evaluation of pulmonary function,² nutritional status,²¹ and optimization of perioperative hemodynamics given the propensity for higher blood loss in polio patients.^{3,8}

The average correction rate achieved in our study of 22 patients with poliomyelitis was 33% at 2-year follow-up. Previously, Mayer et al.¹⁰ reported a curve correction of 49% in primary scoliosis surgery in children for PD and a 1.8% pseudarthrosis rate over a 12-month follow-up period. Similarly to Leong et al.,⁹ we found four patients (18%) that developed pseudarthrosis in an average 82-month follow-up period. Eberle et al.⁷ reported a 40% rate of pseudarthrosis and a 94% curve progression rate following long spinal fusion without arthrodesis in 1988. Most recently, Lee et al.²² reported an average 48% curve correction with satisfactory clinical improvement in 5 post-polio patients with scoliosis.

Although no prior studies report subjective outcome scores for PD, authors have recognized improved mobility, enhanced lifestyle, and improvement in tasks of daily living following deformity correction.²¹ Here, we found that the SRS-22 domains of satisfaction, pain, and self-image satisfied the minimum clinically important differences (MCID) suggested by Bago et al.,²³ although with 50% loss to follow-up. Such significant subjective benefit in PD may be attributable to greater pre-operative disability and limited functional reserve, with smaller gains in maintenance of upright posture and decreased trunk fatigue having a greater impact on quality of life.

The 45% rate of major complication in the current study was lower than reported in the past, however significantly higher than the 0.7–17.3% complication rate reported in modern adult scoliosis surgery.^{14,24,25} Similar to past findings, complications in the current study were more likely in older adults and those undergoing spinal osteotomy.^{26,27} This suggests that while the overall risk factors remain the same, the higher rate of complications may reflect the increased age, lower bone quality, increased propensity for blood loss, and the neuromuscular disease associated with the spinal deformity.²⁸

It is unclear whether patients with poliomyelitis are at elevated risk of infection than patients with adolescent idiopathic scoliosis (AIS). While Leong et al.⁹ and Eberle et al.⁷ reported a 20% rate of postoperative infections, much like Mayer et al.,¹⁰ we found only a 4% incidence (1/22, 4%) of infection. This low infection rate may reflect improving surgical practices in regard to sterility as well as the introduction of routine vancomycin powder use for surgical site infection prophylaxis in spinal surgery at our institution.²⁹

Due to the uniqueness of the diagnosis, we are confident that this study captures all patients with a history of poliomyelitis infection who have undergone surgical reconstruction at our institution. Conversely, the study has known limitations and biases relating to the small sample size, a product of the unique diagnosis, and the retrospective design. Not all patients received longitudinal care at our facilities, and due to the variable rate of follow-up, the true incidence of long-term complications is uncertain. Analysis of such a small cohort precludes accurate multivariate regression and as a result our calculated odds ratios should be interpreted with caution. This fact is reinforced by the wide confidence intervals; a result of the small numbers of events and patients. Additionally, non-consecutive outcomes data were available for only 50% of the patients undergoing surgery; our results may overestimate the true effect of spinal surgery in patients with a history of poliomyelitis, as those patients with poor outcomes may have refused or been unable to complete the postoperative questionnaires.

Despite these limitations, this study provides a modern perspective on the surgical management of poliomyelitis associated spinal deformity. We demonstrate a high rate of perioperative morbidity following spinal reconstruction for deformity correction in patients with history of poliomyelitis. Neurological complications occurred in a high proportion of patients, with a low efficacy of intraoperative monitoring. Our findings of increased risk in older patients and those undergoing revision surgery or spinal osteotomy are consistent with those reported in the literature. Despite these increased risks associated with surgery, good subjective outcomes may be expected for patients undergoing reconstruction for poliomyelitis associated spinal deformities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The manuscript submitted does not contain information about medical device(s)/drug(s). The Washington University Institute of Clinical and Translational Sciences grants UL1 TR000448 and TL1 TR000449 from the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health (NIH) funds were received in support of this work. Relevant financial activities outside the submitted work: board membership, grants, royalties, travel/accommodations/meeting expenses.

References

1. Dalakas MC, Elder G, Hallett M, et al. A long-term follow-up study of patients with post-poliomyelitis neuromuscular symptoms. *N Engl J Med*. 1986; 314:959–63. [PubMed: 3007983]
2. Gonzalez H, Olsson T, Borg K. Management of postpolio syndrome. *Lancet Neurol*. 2010; 9:634–42. [PubMed: 20494327]
3. Jubelt B. Post-Polio Syndrome. *Curr Treat Options Neurol*. 2004; 6:87–93. [PubMed: 14759341]
4. Kumakura N, Takayanagi M, Hasegawa T, et al. Self-assessed secondary difficulties among paralytic poliomyelitis and spinal cord injury survivors in Japan. *Arch Phys Med Rehabil*. 2002; 83:1245–51. [PubMed: 12235604]
5. Ramlow J, Alexander M, LaPorte R, et al. Epidemiology of the post-polio syndrome. *Am J Epidemiol*. 1992; 136:769–86.
6. Bruno RL, Frick NM, Cohen J. Polioencephalitis, stress, and the etiology of post-polio sequelae. *Orthopedics*. 1991; 14:1269–76. [PubMed: 1758794]
7. Eberle C. Failure of Fixation Arthrodesis after Segmental Instrumentation Scoliosis without in the Management of Paralytic. *J Bone Joint Surg Br*. 1988; 70-A:696–703.
8. Warltier DC, Ph D, Lambert DA, et al. Postpolio Syndrome and Anesthesia Poliomyelitis: Acute Illness and Recovery. *Anesthesiology*. 2005; 103:638–44. [PubMed: 16129991]
9. Leong R, One OF, Wilding H, et al. Surgical Treatment of Scoliosis following Poliomyelitis. *J Bone Joint Surg Br*. 1981
10. Mayer P, Dove J, Ditmanson M, et al. Pos-Poliomyelitis Paralytic Scoliosis: A Review of Curve Patterns and Results of Surgical Treatments in 118 Consecutive Patients. *Spine*. 1981; 6:573–82. [PubMed: 7336280]
11. Ring D, Vaccaro aR, Scuderi G, et al. An association between the flat back and postpolio syndromes: a report of three cases. *Arch Phy*. 1997; 78:324–6.
12. Glassman S, Berven S, Bridwell K, et al. Correlation of Radiographic Parameters and Clinical Symptoms in Adult Scoliosis. *Spine (Phila Pa 1976)*. 2005; 30:682–8. [PubMed: 15770185]
13. Padberg A, Bridwell K. Spinal cord monitoring: current state of the art. *Orthop Clin North Am*. 1999; 30:407–33. [PubMed: 10393764]

14. Cho SK, Bridwell KH, Lenke LG, et al. Comparative analysis of clinical outcome and complications in primary versus revision adult scoliosis surgery. *Spine*. 2012; 37:393–401. [PubMed: 21540777]
15. Hamilton DK, Smith JS, Sansur Ca, et al. Rates of new neurological deficit associated with spine surgery based on 108,419 procedures: a report of the scoliosis research society morbidity and mortality committee. *Spine*. 2011; 36:1218–28. [PubMed: 21217448]
16. Owen J, Sponseller P, Szymanski J, et al. Efficacy of Multimodality Spinal Cord Monitoring During Surgery for Neuromuscular Scoliosis. *Spine (Phila Pa 1976)*. 1995; 20:1480–8. [PubMed: 8623067]
17. Hammett TC, Boreham B, Quraishi Na, et al. Intraoperative spinal cord monitoring during the surgical correction of scoliosis due to cerebral palsy and other neuromuscular disorders. *Eur Spine J*. 2013; 22(Suppl):S38–S41. [PubMed: 23344681]
18. Phillips LH, Blanco JS, Sussman MD. Direct spinal stimulation for intraoperative monitoring during scoliosis surgery. *Muscle & nerve*. 1995; 18:319–25. [PubMed: 7870110]
19. Schwartz DM, Drummond DS, Ecker ML. Influence of rigid spinal instrumentation on the neurogenic motor evoked potential. *J Spinal Disord*. 1996; 9:439–45. [PubMed: 8938615]
20. Gyermek L. Increased Potency of Nondepolarizing Relaxants After Poliomyelitis. *J Clin Pharmacol*. 1990; 30:170–3. [PubMed: 2312770]
21. Siegel, I. Post-Polio Health. Post-Polio Corrective Spinal Surgery Now.
22. Lee DY, Choi IH, Chung CY, et al. Fixed pelvic obliquity after poliomyelitis: classification and management. *J Bone Joint Surg Br*. 1997; 79:190–6. [PubMed: 9119840]
23. Bagó J, Pérez-Grueso FJS, Les E, et al. Minimal important differences of the SRS-22 Patient Questionnaire following surgical treatment of idiopathic scoliosis. *Eur Spine J*. 2009; 18:1898–904. [PubMed: 19533179]
24. Carreon LY, Puno RM, Lenke LG, et al. Non-neurologic complications following surgery for adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2007; 89:2427–32. [PubMed: 17974885]
25. Bago J, Ramirez M, Pellise F, et al. Survivorship analysis of Cotrel-Dubousset instrumentation in idiopathic scoliosis. *Eur Spine J*. 2003; 12:435–9. [PubMed: 12827472]
26. Cho SK, Bridwell KH, Lenke LG, et al. Major complications in revision adult deformity surgery: risk factors and clinical outcomes with 2- to 7-year follow-up. *Spine*. 2012; 37:489–500. [PubMed: 21587110]
27. Sansur C, Smith J, Coe J, et al. Scoliosis research society morbidity and mortality of adult scoliosis surgery. *Spine*. 2011; 36:E593–7. [PubMed: 21325989]
28. Marafi F, Al-Said Ali A, Esmail A, et al. Baseline patterns of bone scintigraphy in patients with established post-poliomyelitis paralysis. *Skeletal radiology*. 2010; 39:891–5. [PubMed: 19593558]
29. Sweet, Fa; Roh, M.; Sliva, C. Intrawound application of vancomycin for prophylaxis in instrumented thoracolumbar fusions: efficacy, drug levels, and patient outcomes. *Spine*. 2011; 36:2084–8. [PubMed: 21304438]