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Spinal Fusion With Cotrel-Dubousset Instrumentation for Neuropathic Scoliosis in Patients With Cerebral Palsy

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Study Design. Retrospective.

Objective. To report on the treatment of patients with cerebral palsy and neuropathic scoliosis with third-generation instrumented spinal fusion by Cotrel-Dubousset instrumentation.

Summary of Background Data. Second-generation instrumented spinal fusion is considered the standard for progressive neuropathic scoliosis in cerebral palsy, despite high complication rates. Evidence is needed to evaluate the increasing use of third-generation instrumented spinal fusion in similar patients.

Methods. Patients with cerebral palsy and spinal deformity treated consecutively by 1 surgeon with Cotrel-Dubousset instrumentation and minimum 2-year follow-up were reviewed. An outcome questionnaire was administered at final follow-up.

Results. A total of 60 patients were included. Mean age was 15 years at surgery. Mean follow-up was 79 months. There were 26 anteroposterior and 34 posterior-only procedures. Correction of coronal deformity and pelvic obliquity averaged 60% and 40%, respectively. Major complications affected 13.5% of patients, and included implant loosening, deep infection, and pseudarthrosis. Minor complications affected 10% of patients. Outcome questionnaires showed marked improvements in the areas of satisfaction, function, and quality of life after surgery.

Conclusions. Segmental, third-generation instrumented spinal fusion provides lasting correction of spinal deformity and improved quality of life in patients with cerebral palsy and neuropathic scoliosis, with a lower pseudarthrosis rate compared to reports on second-generation instrumented spinal fusion.

Key words: neuropathic scoliosis, cerebral palsy, spinal fusion. **Spine 2006;31:E441–E447**

The Scoliosis Research Society classifies neuromuscular spinal deformities as "neuropathic" when caused by upper or lower motor neuron lesions. Most of the knowledge about neuropathic scoliosis regards patients with cerebral palsy.[1] Cerebral palsy is a nonprogressive but often changing motor impairment syndrome secondary to lesions or anomalies of the upper motor neuron, occurring in the early stages of development, affecting 2–2.5/1000 live births.[2] It is described by type of motor disorder (spastic, ataxic, dystonic, and dyskinetic), topographic body involvement (hemiplegia, diplegia, and tetraplegia), and gross motor function (Table 1).[3]

The prevalence of spinal deformities in patients with cerebral palsy ranges from 10% of ambulatory patients with spastic hemiplegia to 65% of those with spastic quadriplegia. Deformity in patients with cerebral palsy can continue to progress into adulthood. In ambulatory patients, the trunk may become so distorted that standing erect becomes impossible. In nonambulatory patients, sitting may become more difficult with increasing pelvic obliquity. Therefore, the goals of surgery are to arrest progression of the deformity and improve the balance of the spine.

Segmental instrumented spinal fusion with second-generation instrumentation (Luque-Galveston and unit rod constructs) has been considered the standard surgical treatment of neuromuscular deformity in the last 2 decades, despite major complication rates reaching 40% to 50% in treated patients.[1,4,5] Third-generation systems, including Cotrel-Dubousset instrumentation and similar designs, have virtually eliminated postoperative casts or braces and lowered pseudarthrosis rates in idiopathic spinal deformity surgery. Nevertheless, there are few reports on the results of third-generation instrumented spinal fusion for the treatment of neuromuscular scoliosis,[6–8] and none for patients exclusively affected by cerebral palsy and spinal deformity. Therefore, the aims of this study are to evaluate the outcome of treatment of spinal deformity caused by cerebral palsy with segmental, third-generation instrumented spinal fusion, and compare the results with those previously published on both second and third-generation instrumented spinal fusion in similar patients.

■ Materials and Methods

Inclusion criteria were a diagnosis of progressive spinal deformity caused by cerebral palsy, treatment by instrumented spinal fusion with third-generation instrumentation, and minimum 2-year follow-up. Exclusion criteria were incomplete clinical and/or radiologic documentation at follow-up. Patients were assessed before and after surgery in the senior author's outpatients' clinic. The coronal and sagittal components of the spinal deformity were measured by the Cobb method on full spine sitting or standing (before surgery, supine traction/bending) radiographs. Pelvic obliquity was the angle described by a line tangential to both iliac crests, and a line perpendicular to the spinous processes of L4 and L5.[9] When instrumentation

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Table 1. Patients' Preoperative and Follow-up Functional Levels

	Study Cohort (n = 60) Preoperative/Follow-up	Group 1 (n = 34) Preoperative/Follow-up	Group 2 (n = 26) Preoperative/Follow-up
WHO functional level 1: walkers without devices	—/2	—/2	—/—
WHO functional level 2: walkers with limitations in community walking	6/2	6/2	—
WHO functional level 3: walkers with mobility devices	8/10	4/6	4/4
WHO functional level 4: self-mobilized with either transport or power mobility outdoors	6/6	6/6	—
WHO functional level 5: self-mobilized with severe limitations	40/40	18/18	22/22

Adapted with permission from World Health Organization.[3]

or fusion mass made this measurement unreliable, we drew a line intersecting the middle of the pedicles of L4 and L5 on the posteroanterior view. There were 2 observers who independently performed the measurements. Intraobserver and interobserver reliability were assessed using the kappa statistic. Indications for surgery were based on the magnitude and progression of spinal deformity, and presence of functional deterioration. Cardiopulmonary and nutritional status were evaluated as part of the preoperative screening.[1,4–6]

Posterior-only instrumented spinal fusions were planned for skeletally mature patients with flexible deformities (more than 50% correction on traction/bending films) and when cardiopulmonary function did not allow double approaches. Anteroposterior spinal fusions were planned in case of deformities correcting less than 50% on traction/bending films, fixed pelvic obliquity, deficiency of posterior elements, or skeletal immaturity.[1,4–7] Staged procedures were preferred, with anterior procedures preceding posterior ones.[1,5–7] Fusion to the pelvis was planned for nonambulatory patients with sitting unbalance, in case of curves including the pelvis or fixed pelvic obliquity. Stainless steel Cotrel-Dubousset (Medtronic Sofamor Danek, Memphis, TN) instrumentation was always used.

In anterior thoracic or thoracoabdominal approaches, the harvested rib was morselized and used as interbody graft. Segmental vertebral vessels were tied before release of the anterior longitudinal ligament, discectomy, and removal of vertebral endplates. Coralline hydroxyapatite was added to the rib autograft in interbody spaces. No instrumentation was used anteriorly. Patients were then transferred to an intensive care unit (ICU), where pulmonary care and fluid balance were accomplished until extubation and achievement of homeostasis.

Before posterior approaches, corticocancellous grafts from the medial aspect of 1 or both tibial diaphyses were harvested when fusion to the pelvis had been planned.[7,8] Next, patients were positioned prone on a 4-poster Cotrel table with halo and bilateral lower limb skin traction.[7] After facetectomy, laminar, pedicle, and transverse process hooks were used at thoracic levels, with a claw configuration of the uppermost thoracic hooks. Disruption of the posterior ligaments proximal to the uppermost level of fusion was avoided. Laminar hooks and pedicle screws were positioned at thoracolumbar and lumbar levels. Sublaminar wires were often used in the concavity of the lumbar deformity. Two 4.5 or 5.5-mm diameter rods linked by cross connectors were implanted. The tibial grafts were impacted beneath the instrumentation in the thoracolumbar and lumbosacral area.[7,8] The technique of iliosacral fixation followed the steps already described.[7,8]

Deformity correction was obtained by contouring the rods, translation, and segmental compression/distraction. The halo was removed before the patient left the operating room. Cell-savers and controlled hypotensive anesthesia (with a mean blood pressure around 65-mm Hg) were used. Spinal cord monitoring was not used. First-generation intravenous cephalosporins[5] were continued for 72 hours.

After surgery, enteral or parenteral hyper alimentation was used in case oral feeding was not possible, especially between surgical stages. Mobilization to a molded wheelchair or ambulation was encouraged with the assistance of specialized physiotherapists. No cast or brace was prescribed after surgery. Clinical and radiologic outpatients' follow-up was performed at 3, 6, 12 months after surgery, and yearly thereafter. Because at the time of patients' review no validated questionnaire existed for evaluation of spastic neuromuscular scoliosis, an outcome questionnaire already validated for flaccid neuromuscular scoliosis[10] was mailed to patients and their parents or caregivers at the final follow-up.

Clinical and radiographic data were subdivided among treatment groups: posterior-only (group 1) and anteroposterior-staged (group 2) surgeries. We considered all parameters previously described for evaluation of the surgical outcome in similar cohorts.[1,4–8,10,11] Complications were divided into major and minor according to their effect on the course of recovery in hospital and on their potential life, limb, or function threatening effect.[4,5,11] For statistical analysis, Pearson correlation analysis was applied to data by a SPSS program (SPPS Inc., Chicago IL). The χ^2 test was used to evaluate differences between groups. For all comparisons, a P value <0.05 (2-tailed) was considered significant.

■ Results

A total of 64 patients consecutively treated from September 1991 to January 2003, were eligible for inclusion in the study. Authors who had not been involved in patients' care analyzed patients' medical records and imaging. Intraobserver agreement for deformity angle measurements on preoperative, postoperative, and follow-up radiographs was excellent for both observers (k = 0.89, 0.83, and 0.86 for observer 1, and k = 0.80, 0.79, and 0.87 for observer 2, respectively). Interobserver concordance was k = 0.72 (good agreement) for preoperative radiographs, k = 0.69 (good agreement) for postoperative radiographs, and k = 0.74 (good agreement) for radiographs at final follow-up. There were 4 patients excluded because of incomplete records.

Of the 60 patients, including 42 females and 18 males, in the study, mean age at surgery was 15 ± 3 years (range

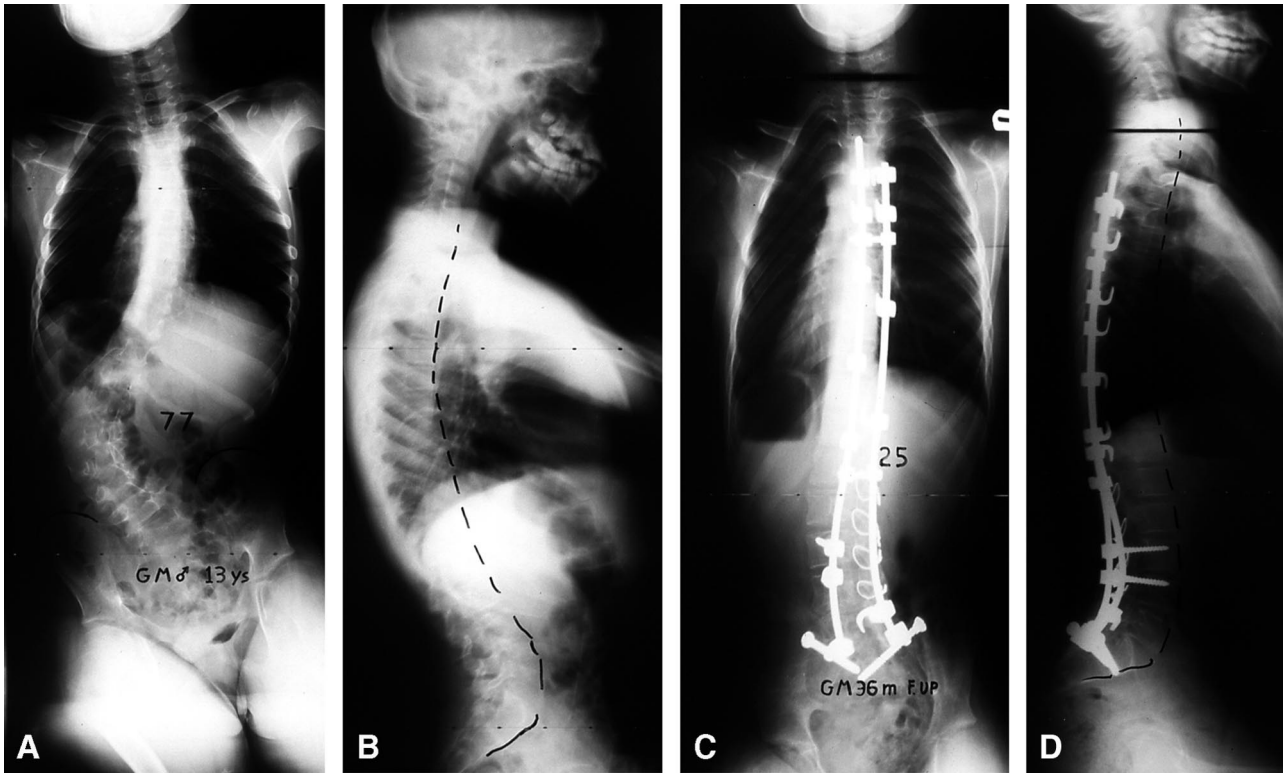

Figure 1. **A** and **B**, Posteroanterior and lateral preoperative radiographs of a 13-year-old male patient with spastic quadriplegia treated in 1998. **C** and **D**, Posteroanterior and lateral radiographs 3 years following posterior spino-pelvic fusion with tibial autograft.

8–24), and mean follow-up was 79 ± 39 months (range 31–160). Etiology of spinal deformity included spastic quadriplegia in 46 patients and spastic hemiplegia in 14. The corresponding preoperative and follow-up functional levels, according to the World Health Organization (WHO) classification of impairment, activity, and participation,[3] are displayed in Table 1.

There were 34 posterior-only procedures (group 1; Figure 1) and 26 anteroposterior staged procedures (group 2; Figure 2). There were 7 ± 3 days spent on average between procedures in group 2. Gender distribution was 24 females-10 males in group 1 and 18 females-8 males in group 2. Mean age at surgery was 15 ± 3 years in group 1 and 15 ± 2 years in group 2 ($P >$

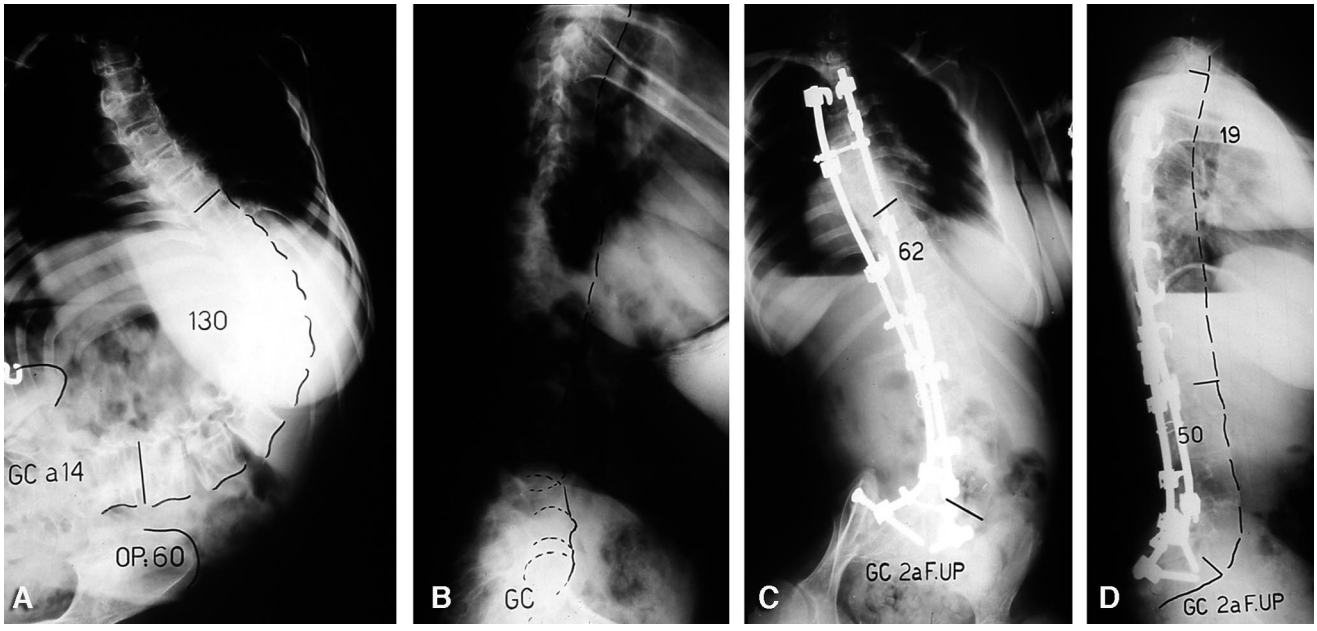

Figure 2. **A** and **B**, Posteroanterior and lateral preoperative radiographs of a 14-year-old female patient with spastic quadriplegia treated in 1995. **C** and **D**, Posteroanterior and lateral radiographs 2 years following anteroposterior spino-pelvic fusion with tibial autograft.

0.05). Mean weight at surgery was 40 ± 3 kg in group 1 and 40 ± 4 kg in group 2 ($P > 0.05$). Functional levels differed between groups: 24/34 (70%) patients in group 1 had level 4 or 5 (wheelchair bound), as opposed to 22/26 in group 2 (85%, $P < 0.05$), reflecting the prevalence of spastic quadriplegia (20/26 patients) in group 2. Mean follow-up time was 81 ± 45 and 78 ± 37 months in groups 1 and 2, respectively ($P > 0.05$). At surgery 18 patients in group 1 and 6 in group 2 were skeletally mature. On average, 4 ± 1 levels were operated on the 26 anterior and 14 ± 3 levels on the 60 posterior procedures. Proximal instrumentation limit was T1–T2 in 22 cases (37%), T3 in 12 (20%), and T4–T5 in 26 (43%).

Of 60 posterior fusion procedures, 40 (67%) included the pelvis (Figures 1, 2). Pediatric 4.5-mm rods were used in 6 of 60 (10%) posterior surgeries. Mean operating time was 314 ± 86 minutes in group 1 and 507 ± 100 minutes in group 2 ($P < 0.05$). Mean intraoperative blood loss was 1500 ± 647 mL in group 1 (41% of EBV) and 1562 ± 629 mL in group 2 (43% of EBV, $P > 0.05$). Time spent in ICU was not significantly different between groups (3.9 ± 2.2 and 3.9 ± 2.3 days in group 1 and 2, respectively). Hospital stay was longer in group 2 (11 ± 4.8 days on average) than in group 1 (9 ± 4.1 days, $P < 0.05$).

In the study cohort, preoperative functional status was positively correlated with scoliosis ($r = 0.41$, $P < 0.05$) and kyphosis ($r = 0.30$, $P < 0.05$) Cobb angles. Intraoperative blood loss was positively correlated with several other factors, namely, pelvic obliquity both in groups 1 ($r = 0.38$, $P < 0.05$) and 2 ($r = 0.46$, $P < 0.05$), age at surgery in group 2 ($r = 0.43$, $P < 0.05$), and operating time in group 1 ($r = 0.39$, $P < 0.05$). Major complications affected 8 patients (13.3%), including 5 in group 1 and 3 in group 2 ($P < 0.05$). In group 1, there were 2 cases of low-grade deep infection resolved with debridement and removal of instrumentation after 2 years from the index surgery. There was 1 case of pseudarthrosis in the lumbar area that was evident 4 years after surgery and healed after a revision procedure. One case of iliosacral screw misplacement was revised because of S1 radicular pain and 1 case of nonfatal postoperative disseminated intravascular coagulation was complicated by respiratory distress syndrome. In group 2, there were 3 cases of loosening of proximal thoracic hooks necessitating revision. There were no permanent neurologic complications or deaths during the follow-up period in the study cohort.

Minor complications affected 6 patients (10%), including 4 in group 1 and 2 in group 2 ($P < 0.05$). In group 1, there were 2 cases of superficial wound infection and 2 cases of urinary tract infection, all resolved with oral antibiotics. In group 2, there was 1 case of superficial wound infection resolved with oral antibiotics and 1 case of thoracic hook loosening not necessitating removal. No donor site complications, particularly leg length discrepancy or fracture,[8] were observed in patients in whom tibial autografts had been harvested.

Table 2. Evaluation Questionnaire Scores

	Study Cohort (n = 52)	Group 1 (n = 30)	Group 2 (n = 22)
Cumulative	30.6	32.5	29.9
Cosmesis	4.8	4.7	4.8
Function	7.4	7.9	6.7
Self-image	2.2	2.2	2.2
Pain	0.7	0.9	0.4
Patient care	3.3	3.6	3.2
Pulmonary function	0.6	0.9	0.4
Quality of life	5.3	5.4	5.2
Satisfaction	8.4	8.6	8.2

All values are expressed as means.
Adapted from *Spine* 1999;24:1300–9.[10]

A total of 52 (87%) patients or parents/caregivers returned outcome questionnaires[10] (Table 2). There were 8 patients who had changed their address at the time of the postal survey, and we have been unable to track their new addresses. Mean cumulative score was 30 ± 10 in the study cohort: 32 ± 12 in group 1 (n = 30) and 29 ± 11 in group 2 (n = 22, $P > 0.05$). The highest scores in both groups were recorded in the areas of satisfaction, quality of life, function, and cosmesis, with satisfaction ranking highest.

Table 3 summarizes the main radiographic data. On average, preoperative scoliosis, kyphosis, and lordosis angles were not significantly different in the 2 groups. Preoperative pelvic obliquity was significantly lower in group 1 than in group 2 (15° ± 6° *vs.* 19° ± 13° respectively, $P < 0.05$). Correction of scoliosis was statistically significant within groups, but no differences were significant among groups. At follow-up, the mean loss of correction of scoliosis was 2° in group 1 and 3° in group 2. Variation of kyphosis values compared with preoperative values was all statistically significant within groups, but no differences were significant among groups. At follow-up, kyphosis values changed nonsignificantly both in groups 1 (2°) and 2 (4°). Variation of lordosis angles prevailed nonsignificantly in group 1 (5° *vs.* 3° in group 2). At follow-up, lordosis angles changed nonsignificantly in both groups by 3°. Correction of pelvic obliquity compared to preoperative values was statistically significant in both groups, without significant changes at follow-up. Improvement of coronal balance compared to preoperative values was statistically significant in both groups, without reaching normality or significantly changing at follow-up.

■ Discussion

Patients with the various types of neuromuscular spinal deformity benefit from spinal fusion, particularly in the areas of nursing, respiratory function, and feeding.[4,7,8,10] This applies to patients with neuropathic deformities caused by cerebral palsy, treated with second-generation segmental instrumented spinal fusion.[1,5] Third-generation instrumented spinal fusion has enhanced correction and allowed early ambulating/nursing

Table 3. Main Radiographic Data

	Study Cohort (n = 60)	Group 1 (n = 34)	Group 2 (n = 26)
Scoliosis preop Cobb angle (flexibility on bending/traction films)	75° ± 19° (49%)	74° ± 22° (56%)	76° ± 20° (40%)
Scoliosis postop Cobb angle (correction)	31° ± 12° (59%) $P < 0.05$	31° ± 13° (58%) $P < 0.05$	31° ± 11° (59%) $P < 0.05$
Scoliosis follow-up Cobb angle (lost)	33° ± 13° (1%)	33° ± 13° (1%)	33° ± 12° (1%)
Kyphosis preop Cobb angle	54° ± 24°	53° ± 25°	55° ± 24°
Kyphosis postop Cobb angle	40° ± 13° $P < 0.05$	39° ± 14° $P < 0.05$	41° ± 14° $P < 0.05$
Kyphosis follow-up Cobb angle (lost)	43° ± 15° (1%)	41° ± 16° (1%)	45° ± 13° (2%)
Lordosis preop Cobb angle	57° ± 21°	57° ± 21°	56° ± 21°
Lordosis postop Cobb angle	53° ± 19°	52° ± 21°	53° ± 20°
Lordosis follow-up Cobb angle (lost)	50° ± 16° (−1%)	50° ± 19° (−1%)	50° ± 17° (−1.5%)
Pelvic obliquity preop Cobb angle	16° ± 12°	15° ± 6°	19° ± 13°
Pelvic obliquity postop Cobb angle (correction)	9° ± 8° (45%)	9° ± 5° (40%)	10° ± 7° (47%) $P < 0.05$
Pelvic obliquity follow-up Cobb angle (lost)	9° ± 8° (0%)	9° ± 5° (0%)	10° ± 7° (0%)
Trunk unbalance preop (cm)	4.5 ± 2	4.1 ± 1.5	5.2 ± 2
Trunk unbalance postop (cm)	2.0 ± 1 $P < 0.05$	1.5 ± 1.2 $P < 0.05$	2.2 ± 1.5 $P < 0.05$
Trunk unbalance follow-up (cm)	2.2 ± 1.1 $P > 0.05$	1.5 ± 1.4	2.3 ± 1.4

Values are expressed as mean ± SD.
Preop indicates preoperatively; postop, postoperatively.

without external supports in idiopathic scoliosis surgery, but, so far, there is surprisingly little evidence that the same is true in neuropathic scoliosis surgery.[6–8] Most spinal deformities in cerebral palsy, with or without pelvic involvement, are in spastic patients and characterized by limited flexibility.[1,4–7] Whether best in 1[12,13] or 2 stages,[5,14] anteroposterior spinal fusion increases deformity correction and decreases the risk of pseudarthrosis in neuromuscular scoliosis treated with second-generation instrumentation. With third-generation posterior instrumentation systems, anterior release and fusion with[7] or without[6,7] instrumentation followed by posterior instrumentation has also given satisfactory results.

Limitations of the present study include the retrospective design and absence of an internal control group treated with second-generation implants, making comparison with other investigators' series of patients an absolute necessity from the point of view of operating time, blood loss, hospital stay, deformity correction, and complications. From these studies,[1,4–7] data concerning patients with cerebral palsy were extracted, analyzed, and tabulated (Table 4). We observed that in our cohort, percentage correction of scoliosis was very similar in patients treated posteriorly and anteroposteriorly, although the latter had by definition stiffer curves on preoperative imaging. This result confirms previous published experience.[7] Conversely, correction of pelvic obliquity was significantly higher in patients treated with the double approach, which might suggest a positive role of anterior release of the lumbar spine toward correction of pelvic deformity. The use of intraoperative halo traction[7] did

Table 4. Comparison of Main Clinical and Radiographic Data of the Present Study With Previous Reports on Instrumented Spinal Fusion for Cerebral Palsy-Related Spinal Deformity

Investigator (y)/ Type of Dysfunction	No. Patients/Study Design	Mean Follow-up (mos)	Type of Surgical Approach (% patients)	Type of Implant	Operating Time (min)	Blood Loss (EBV)	Scoliosis Correction (%)	Pelvic Obliquity Correction (%)	Major Complications (% of patients)
Present study/CP	60/retrospective	79	57% post only, 43% anteropost	CDI	395	1551 mL (0.4)	59	45	13.3
Lonstein and Akbarnia[1] (1983)/CP and cognitive impairment	76 with CP/retrospective	54	63% post only, 37% anteropost (cohort)	Harrington, Luque. Dwyer, Zielke	Not reported	4300 mL (1.3; cohort)	63	69	50 (cohort)
Neustadt *et al*[6] (1992)/ neuromuscular	7 with CP/retrospective	28	61% post only, 39% anteropost (cohort)	CDI	330 (cohort)	1945 mL (not reported)	42	50	0 (16.6; cohort)
Miladi and Zeller[7] (1997)/ neuromuscular	41 with CP/retrospective	62	58% post only, 42% anteropost (cohort)	CDI	Not reported	Not reported	53–70	60–84	7.3
Benson *et al*[4] (1998)/ neuromuscular	20 with CP/retrospective	40	74% post only, 26% anteropost (cohort)	Luque-Galveston	402 (cohort)	1839 mL (not reported)	63	75	5 (14; cohort)
Tsirikos *et al*[5] (2003)/CP	45/retrospective	38	100% anteropost	Unit rod	420	2600 mL (1.6)	67	75	43.3

Anteropost indicates anteroposteriorly; CDI, Cotrel-Dubousset Instrumentation; CP, cerebral palsy; post, posteriorly.

not result in cosmetic problems, given the limited period of application, and relieved pressure from the face during posterior surgeries.

Importantly, the improvement of trunk balance and pelvic obliquity (Table 3) led to better sitting balance and the absence of pressure sores at follow-up. There were statistically significant differences in the main indexes of clinical outcome between groups. Patients treated with posterior-only procedures had the shortest hospital stay and operating time, but the highest incidence of major and minor complications, particularly superficial and deep infections. Patients treated with anteroposterior procedures understandably had the longest operating time and highest blood loss. Both parameters, though, did not correlate with time spent in ICU or number of complications. Average intraoperative blood loss in our study cohort (Table 4) is the lowest ever reported in this type of study and was positively correlated with the degree of pelvic obliquity in both groups, an indicator of more extensive procedures necessary with increasing pelvic obliquity. With the numbers available, it is not possible to speculate why complications affected more patients treated only posteriorly because none of the studied parameters was significantly correlated with the number and type of complications.

Early experience with first and second-generation implants in neuromuscular scoliosis showed that pseudarthrosis is more prevalent among patients treated with posterior-only procedures,[1] and with third-generation implants, loss of correction appeared more frequent in the same group of patients.[7] The pseudarthrosis rate detected at an average follow-up of nearly 7 years (1.6%) in the present series is in the lower range compared to previous reports on second-generation instrumented spinal fusion (1.5% to 10%)[1,5] and similar to previous reports on third-generation instrumented spinal fusion[6,7] with shorter follow-ups. A low pseudarthrosis rate might be caused both by the increased stability provided by third-generation instrumentation[6] and the use of corticocancellous tibial autografts.[7,8]

Consequently, we observed at follow-up (Table 3) a minimal loss of correction of scoliosis, kyphosis, and lordosis angles, confirming previous reports with shorter follow-ups.[6,7] Therefore, the higher percentage of major complications in this study cohort compared to similar cohorts treated with third-generation instrumentation is caused by the 3 cases of loosening of thoracic hooks and a fourth case of iliosacral screw misplacement. It is noteworthy that no permanent neurologic complications were observed in the study cohort despite the absence of spinal cord monitoring, as already reported.[6,7] Spinal cord monitoring has been used during spinal fusion with second-generation implants based on thoracic and lumbar sublaminar fixation in patients with neuromuscular scoliosis,[4,5] but somatosensory potentials are very often absent at baseline in patients with cerebral palsy.[15] Nevertheless, promising new technology allowing monitoring of both motor and sensory tracts in patients with cerebral palsy undergoing scoliosis surgery with second-generation implants[16] deserves consideration for use during spinal fusion, even with third-generation implants.

Although surgery performed in patients in the present study had minimal effects on functional levels (Table 1), outcome questionnaires[10] highlighted important gains in the areas of cosmesis, overall function (the sum of scores addressing walking, sitting, feeding abilities, and sleeping habits), and quality of life. It is noteworthy that all responders expressed complete or near-complete satisfaction with surgery and would recommend it to others with the same clinical problems. Based on the results of this study, we conclude that segmental, third-generation instrumented spinal fusion proved able to offer patients with cerebral palsy improved and long-lasting quality of life through correction of their spinal deformity, at the expense of a lower complication rate, particularly pseudarthrosis, than generally reported for second-generation instrumented spinal fusion and without the need for postoperative supports, like casts or braces. Results of this study were comparable to previous reports on third-generation instrumented spinal fusion on similar patients with shorter follow-ups, with the exception of a higher rate of implant loosening requiring revision.

■ Key Points

- Second-generation instrumented spinal fusion has been considered the standard in the treatment of neuropathic deformities over the last 2 decades.
- To provide more evidence on the results of the use of third-generation implants in neuropathic scoliosis, a consecutive series of patients with cerebral palsy treated over 10 years by 1 surgeon by third-generation instrumented spinal fusion and minimum 2-year follow-up was studied retrospectively.
- At an average follow-up of 7 years, segmental third-generation instrumented spinal fusion provided lasting correction of spinal deformity and improved quality of life in these patients, with lower complication rates than those reported for second-generation instrumented spinal fusion.

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