



# Major complications following surgical correction of spine deformity in 257 patients with cerebral palsy

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## Abstract

**Study design** Observational.

**Objectives** To report on the rate of major complications following spinal fusion and instrumentation to treat spinal deformity in patients with cerebral palsy (CP).

**Summary of background data** Understanding the risk of major complications following the surgical treatment of spine deformities in patients with CP is critical.

**Methods** A prospectively collected, multicenter database of patients with CP who had surgical correction of their spinal deformity (scoliosis or kyphosis) was reviewed for all major complications. Patients with  $\geq 2$  year follow-up or who died  $\leq 2$  years of surgery were included. A complication was defined as major if it resulted in reoperation, re-admission to the hospital, prolongation of the hospital stay, was considered life-threatening, or resulted in residual disability. Overall complication and revision rates were calculated for the perioperative (Peri-op; occurring  $\leq 90$  days postoperative) and delayed postoperative (Delayed;  $> 90$  days) time periods.

**Results** Two hundred and fifty-seven patients met inclusion. Seventy-eight (30%) patients had a major complication, 18 (7%) had  $> 1$ . There were 92 (36%) major complications; 64 (24.9%) occurred Peri-op. The most common Peri-op complications were wound ( $n = 16$ , 6.2%) and pulmonary issues ( $n = 28$ , 10.9%), specifically deep infections ( $n = 12$ , 4.7%) and prolonged ventilator support ( $n = 21$ , 8.2%). Delayed complications ( $n = 28$ , 10.9%) were primarily deep infections ( $n = 8$ , 3.1%) and instrumentation-related ( $n = 6$ , 2.3%). There were 42 additional surgeries for an overall unplanned return to the operating room rate of 16% (Peri-op: 8.6%, Delayed: 7.8%). Thirty-six (14.0%) reoperations were spine related surgeries (wound or instrumentation-related). Eleven (4.3%) patients died between 3 months to 5.6 years postoperatively; 4 occurred  $\leq 1$  year of surgery. Two deaths were directly related to the spinal deformity surgery.

**Conclusion** Spinal deformity surgery in CP patients with greater than 2 years of follow-up have a postoperative major complication rate of 36% with a spine-related reoperation rate of 14.0%.

**Level of evidence** Therapeutic-IV.

**Keywords** Complications · Fusion · Cerebral palsy · Neuromuscular scoliosis · Deformity

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## Introduction

Cerebral Palsy (CP) is a disorder characterized by an impairment of movement that results from a non-progressive abnormality in the developing brain. Lack of control and/or spasticity of truncal muscles frequently lead to scoliosis especially when the extent of involvement is more severe. In some cases this scoliosis and pelvic obliquity may create progressive symptoms and functional impairment that may benefit from surgical correction, typically with a spinal instrumentation and fusion from T2 to the pelvis. When compared to idiopathic scoliosis, surgical intervention in the CP population is associated with higher rates of perioperative and postoperative complications [1–3]. This is likely due to differences in co-morbidities and surgical complexity between the two populations.

Depending on the study, complication rates in patients undergoing spinal deformity surgery ranging from 18 to 65% have been reported in the literature [3–5]. The wide discrepancy in rates of complications is likely based on historical data, inclusion of other neuromuscular conditions, and differences in complication criteria. Recently, Samdani et al. reported a 39% complication rate in 127 patients with CP [2]. The presence of a complication was associated with an increased length of ICU stay (7.8 days vs. 3.2).

The decision to pursue surgery in the CP patient should balance the intended outcome with the potential risk of complications. Providing accurate and up-to-date information for known complications with modern day treatment will allow for improved informed consent and better standards for reimbursement in the era of pay for performance. The purpose of this study is to report on the rate of major perioperative and delayed complications in a prospectively enrolled cohort of surgically treated spinal deformity patients with an underlying diagnosis of cerebral palsy and a minimum of 2 years follow-up after the spinal fusion procedure.

## Methods

A prospectively collected (2008–2014), multicenter database of patients with CP who underwent spinal fusion and instrumentation to correct their spine deformity (scoliosis or kyphosis) was reviewed for all major complications. Patients with minimum 2 year follow-up or who died within 2 years of surgery were included. For inclusion into the database, patients had to be age 8–21 years at the time of surgery, have a diagnosis of CP with spinal deformity, and undergo a spinal fusion for a coronal curve  $> 50^\circ$  or a kyphotic deformity from T5–T12  $> 70^\circ$ .

A complication was defined as major if it resulted in reoperation, re-admission to the hospital, a prolongation of the initial hospital stay, was considered life-threatening, or resulted in residual disability. A standardization manual that defined each complication was provided to all participating site research investigators and coordinators. Complications were classified into 1 of 11 categories: Death, Gastrointestinal, Instrumentation, Medical, Neurologic, Pain, Pulmonary, Pseudarthrosis, Reoperation (not otherwise categorized), Surgical Site/Incision (“wound”), and Transfusion. For the full list of complications included within these categories, see Bartley et al. [1]. If more than one related complications occurred, the most severe was the category that was counted in the overall rate. A review of all reported complications was performed first by a research team independent of the surgeon, as then by a subcommittee of study group members to provide consistency and quality assurance. In addition, a secondary review of the complications was performed to confirm if a complication met the defined “major complication” criteria. Demographic and operative data for each patient was analyzed. The deaths, major complications and reoperations were analyzed for the perioperative (occurring  $\leq 90$  days postoperatively) and delayed ( $> 90$  days postoperatively) time periods. Patient caregiver reported outcomes, as assessed using the CPChild questionnaire and Health Utilities Index (HUI3), were evaluated preoperatively and 2 years postoperatively for the entire cohort as well as between those who experienced a complication and those who did not.

## Results

### Demographics

Two hundred and fifty-seven patients met the greater than 2 year follow-up inclusion criteria. The average length of follow-up was  $3.3 \pm 1.6$  years (range 0.1–7.3 including the follow-up for those who died prior to 2 years postoperatively). There was a 67% follow-up rate with minimum 2 years. The average age at time of surgery was  $14 \pm 3$  years. There were 135 males and 122 females. The gross motor function classification system (GMFCS) levels for the cohort were as follows: Level V: 184, Level IV: 45, Level III: 10, Level II: 5, Level I: 1, Level Unavailable: 12. One hundred and ninety (74%) patients had profound to severe mental retardation, 176 (68%) had a history of seizures, 96 (37%) had a history of pneumonia, and 137 (53%) patients required a G-tube for feeding. Scoliosis was the primary deformity in 234 patients (major curve:  $86 \pm 22^\circ$ ) and kyphosis (T2–T12 kyphosis:  $79 \pm 20^\circ$ ) was the primary deformity in 23. The average coronal deformity for the entire cohort was  $82 \pm 25^\circ$ .

The average kyphosis was  $44 \pm 24^\circ$  from T2 to T12, and  $37 \pm 23^\circ$  from T5 to T12. Radiographic measurements for each primary deformity, as well as for the entire cohort can be found in Table 1.

The surgical correction procedures included the following: 227 posterior spinal fusion and instrumentation (PSF) cases, 26 PSF with an anterior release, 3 combined PSF with anterior spinal fusion/instrumentation, and 1 anterior only spinal fusion with instrumentation. The majority of patients were fused proximally between T1 and T3 (94%; range C5–T9) and distally to the pelvis (91%; range L2–Ilium). For all procedures combined, the average operative time was  $425 \pm 174$  min (range 180–1266) and the average EBL was  $1763 \pm 1287$  cc (range 150–8500), with an average of  $972 \pm 904$  cc (range 0–7500) of blood transfused. The average length of hospital stay was  $13 \pm 12$  days (range 3–137) and the average length of days in the ICU was  $5 \pm 6$  (range 0–46). All but 12 patients (95%) were admitted to the ICU postoperatively. On average, patients received ventilator support for  $2.7 \pm 4.2$  days (range 0–39).

### Major complications

Seventy-six (30%) patients had a major complication, 18 (7%) of which had 2–3 major complications. There were a total of 92 (36%) major complications, 64 (24.9%) occurred perioperatively (Table 2). The most common perioperative complications were wound healing related ( $n=16$ , 6.2%) and pulmonary issues ( $n=28$ , 10.9%), specifically deep infections ( $n=12$ , 4.7%) and prolonged ventilator support ( $n=21$ , 8.2%). Delayed complications ( $n=28$ , 10.9%) were primarily deep infections ( $n=8$ , 3.1%) and instrumentation related ( $n=6$ , 2.3%). On average, major complications occurred 5.5 months postoperatively (range immediate to 5.5 years). There was no difference in the distribution of complication based on GMFCS level: Level V: Y-31% vs N-69%, Level IV: Y-24% vs N-76%, Level III: Y-40% vs N-60%, Level II: Y-20% vs N-80%, Level I: Y-0% vs N-100%, Level Unavailable: Y-25% vs N-75%;  $p=0.8$ .

There were 42 additional surgeries for an overall unplanned return to the operating room rate of 16% (Periop: 8.6%, Delayed: 7.8%). Thirty-six (14.0%) surgeries were spine related, with the majority being wound (8.7%) or instrumentation related (2.7%). Table 3 summarizes the indications for the spine-related revision procedures. The single

most frequent indication for reoperation was a deep infection (6.6%). Eleven (4.2%) patients died between 3 months to 5.6 years postoperatively, with 4 occurring within 1 year of surgery. Two deaths were directly related to the spinal deformity surgery and included in the major complication rate. The first death related to the spinal deformity surgery occurred 3 months postoperatively and involved a cerebral infarction due to acute hydrocephalus and *E. coli* meningitis. The second related death followed a viral infection 2 months after being treated for a wound infection. The causes of the non-spine surgery related deaths were varied: gastrointestinal related (3), respiratory related (2), seizure (1), and unknown (3).

### Caregiver reported outcomes

Significant improvements were seen from preoperative to 2 years postoperative for the entire cohort in all CPChild domains and total score: Activities of daily living ( $39 \pm 16$  to  $45 \pm 17$ ,  $p < 0.001$ ), Transferring and Mobility ( $34 \pm 17$  to  $45 \pm 17$ ,  $p < 0.001$ ), Comfort and Emotions ( $75 \pm 21$  to  $82 \pm 18$ ,  $p < 0.001$ ), Communications and Social Interactions ( $54 \pm 30$  to  $57 \pm 28$ ,  $p = 0.048$ ), Health ( $56 \pm 20$  to  $62 \pm 20$ ,  $p < 0.001$ ), Overall Quality of Life ( $62 \pm 24$  to  $71 \pm 23$ ,  $p < 0.001$ ), and Total Score ( $51 \pm 15$  to  $58 \pm 15$ ,  $p < 0.001$ ). No significant difference was observed in HUI Overall Utility Score for the entire cohort from preoperative ( $-0.08 \pm 0.2$ ) to 2 years ( $-0.06 \pm 0.2$ ) ( $p = 0.2$ ).

The change from preoperative to 2 years postoperative in all CPChild domains was not significantly different based on whether a major complication occurred or not (Table 4). However, the complication group had a HUI score that worsened slightly ( $-0.08$  to  $-0.10$ ), whereas the no complication group showed a modest improvement ( $-0.08$  to  $-0.03$ )  $p = 0.035$ .

### Discussion

Surgery for scoliosis in patients with CP can come with high risks due to the comorbidities associated with this condition. Having current and accurate information regarding major complications following spinal fusion and instrumentation for significant scoliosis and/or kyphosis in the CP patient is important in weighing the costs against the benefits when

**Table 1** Radiographic data

Primary deformity	Major coronal curve magnitude ( $^\circ$ )	T2–T12 kkyphosis ( $^\circ$ )	T5–T12 kyphosis ( $^\circ$ )	Pelvic obliquity ( $^\circ$ )
Scoliosis	$86 \pm 22$	$40 \pm 21$	$34 \pm 20$	$29 \pm 15$
Kyphosis	$47 \pm 21$	$79 \pm 20$	$70 \pm 20$	$17 \pm 14$
Total cohort	$82 \pm 25$	$44 \pm 24$	$37 \pm 23$	$28 \pm 16$

**Table 2** Major complications by categories

Complication type	Total	Peri-operative	Delayed	Additional surgeries (all causes)	Spine-related reoperations
Gastrointestinal	6 (2.3%)	4 (1.6%)	2 (0.8%)	3 (1.2%)	0 (0%)
Difficulty swallowing (1 with increased abdominal distention and silent aspirations)	3	2	1	2	0
Superior mesenteric artery syndrome	2	1	1		
Abdominal distention and/or leakage at gastrostomy tube site	1	1	0	1	0
Surgery related death	2 (0.8%)*	1 (0.4%)	1 (0.4%)	0 (0%)	0 (0%)
Instrumentation	7 (2.7%)	1 (0.4%)	6 (2.3%)	7 (2.7%)	7 (2.7%)
Loss of connection between implants			2	2	2
Loss of fixation to bone			2	2	2
Prominent Hardware		1	1	2	2
Broken rod			1	1	1
Medical	15 (5.8%)	11 (4.3%)	4 (1.6%)	4 (1.6%)	2 (0.8%)
Hypotension (1 resulting in renal failure, 1 with late onset shock presumably due to adrenal insufficiency)		3	2		
Deep vein thrombosis		2	1		
Broken central line wire		1		1	
Dural tear/leak			1	1	1
Hematuria intraoperatively		1		1	1
Inotrope resistant shock and presumed adrenal insufficiency		1			
Myocardial infarction		1			
Peritonitis, acute vascular insufficiency of intestine, abscess, bowel necrosis and perforation		1		1	
Urinary tract infection requiring hospital readmission		1			
Neurologic	1 (0.4%)	1 (0.4%)	0 (0%)	0 (0%)	0 (0%)
Bladder urinary retention	1				
Pseudarthrosis	2 (0.8%)	0 (0%)	2 (0.8%)	2 (0.8%)	2 (0.8%)
Pseudarthrosis (only) requiring revision			1	1	1
Pseudarthrosis with broken rod, requiring revision			1	1	1
Pulmonary	31 (12.1%)	28 (10.9%)	3 (1.2%)	1 (0.4%)	0 (0%)
Prolonged ventilator support (failed initial extubation)		21			
Systemic Inflammatory response syndrome		4	1		
Pneumonia		2	2	1	
Pneumothorax requiring chest tube		1			
Reoperation	3 (1.2%)	1 (0.4%)	1 (0.4%)	3 (1.2%)	3 (1.2%)
Proximal junctional kyphosis		1	1	2	2
Unplanned staged procedure due to intraoperative blood loss		1		1	1
Wound	25 (9.7%)	16 (6.2%)	9 (3.5%)	22 (8.6%)	22 (8.6%)
Infection—deep		12	8	17	17
Dehiscence		1	1	2	2
Infection—superficial		2		2	2
Retained drain		1		1	1
Total	92 (35.8%)	64 (24.9%)	28 (10.9%)	42 (16.3%)	36 (14.0%)

\*Nine additional deaths unrelated to the spine surgeries were reported during the follow-up period: gastrointestinal related (2), respiratory related (2), seizure (1), and unknown (3)

educating a family on whether to pursue surgery for patients in this population. Therefore, the current study reports on the major complications, both perioperative and delayed, in

a large prospectively collected series of surgically treated patients with CP and spinal deformity.

This study is not without limitations. As these patients have frequent comorbidities, it is challenging to identify

**Table 3** Spine related reoperations

	Spine-related reoperations		
	Total	Perioperative	Delayed
Gastrointestinal	0 (0%)	0 (0%)	0 (0%)
Death	0 (0%)	0 (0%)	0 (0%)
Instrumentation	7 (2.7%)	1 (0.4%)	6 (2.3%)
Broken rod	1 (0.4%)	0 (0%)	1 (0.4%)
Loss of connection between implants	2 (0.8%)	0 (0%)	2 (0.8%)
Loss of fixation to bone	1 (0.4%)	0 (0%)	1 (0.4%)
Prominent hardware	2 (0.8%)	1 (0.4%)	1 (0.4%)
Other	1 (0.4%)	0 (0%)	1 (0.4%)
Medical	2 (0.8%)	1 (0.4%)	1 (0.4%)
Dural tear/leak	1 (0.4%)	0 (0%)	1 (0.4%)
Other	1 (0.4%)	1 (0.4%)	0 (0%)
Neurologic	0 (0%)	0 (0%)	0 (0%)
Pseudarthrosis	2 (0.8%)	0 (0%)	2 (0.8%)
Pseudarthrosis—only	1 (0.4%)	0 (0%)	1 (0.4%)
Pseudarthrosis with broken rod	1 (0.4%)	0 (0%)	1 (0.4%)
Pulmonary	0 (0%)	0 (0%)	0 (0%)
Reoperation (PJK, unplanned staged procedure)	3 (1.2%)	2 (0.8%)	1 (0.4%)
Deep Infection	17 (6.6%)	9 (3.5%)	8 (3.1%)
Wound—other (Superficial infection, dehiscence, other)	5 (1.9%)	4 (1.6%)	1 (0.4%)
<b>Total</b>	<b>36 (14.0%)</b>	<b>15 (5.8%)</b>	<b>21 (8.3%)</b>

**Table 4** Comparison of changes in preoperative to postoperative patient/caregiver reported outcomes based on whether patients experienced a complication or not

	Preoperative		2 years postoperative		Change from pre to 2 years based on complication group <i>p</i> value
	Yes complication	No complication	Yes complication	No complication	
<b>CPCHILD</b>					
Personal care—activities of daily living	38 ± 15	40 ± 16	42 ± 18	46 ± 17	0.3
Positioning, transferring and mobility	34 ± 16	34 ± 18	42 ± 19	46 ± 17	0.2
Comfort and emotions	71 ± 21	76 ± 21	78 ± 22	84 ± 16	0.9
Communications and social interactions	53 ± 31	54 ± 29	52 ± 29	58 ± 28	0.2
Health	54 ± 20	57 ± 20	59 ± 19	63 ± 20	0.6
Overall quality of life	59 ± 25	64 ± 23	66 ± 26	74 ± 22	0.7
Total score	50 ± 16	52 ± 14	54 ± 17	59 ± 14	0.1
<b>HUI3</b>					
Overall utility score	− 0.08 ± 0.28	− 0.08 ± 0.23	− 0.11 ± 0.25	− 0.03 ± 0.24	0.035*

\*Statistically significance difference based on repeated measures ANOVA

the relative contribution of the surgery versus the patient’s overall health to any given postoperative complication. Whereas some major complications are clearly associated with the surgery (e.g., broken rod), others may be partially attributable to a pre-existing condition (e.g., failed extubation in a patient with limited respiratory function). Additionally, this study was a multicenter study with each

site responsible for self-reporting postoperative complications. However, to help reduce the variability in reporting, a standardization manual was provided to all sites and a quality assurance review was conducted by a research team independent of the surgeon, as well as by a subcommittee of study group members to provide consistency and quality assurance. Finally, all complications were again

reviewed by the authors to confirm the “major” complication categorization.

Of the 257 patients, 76 patients (30%) experienced 92 major complications giving an overall rate of 36% (25% perioperative), with a reoperation rate of 16%. There was a 14% reoperation rate for spine-related revisions. The majority of all complications were pulmonary (12.1%), wound (9.7%), or medical (5.8%) related.

The risk of pulmonary problems in neuromuscular patients following spinal surgery is well known and includes respiratory failure, aspiration, pneumonia, pneumothorax, or pleural effusion [2, 6, 7]. Rates between 17 and 50% have been reported in the literature [6–9]. Scoliosis surgery has been shown to produce a transient decrease in vital capacity in all patients [10]. Therefore, neuromuscular patients with pre-existing pulmonary compromise should be identified before surgery to optimize lung function. These patients will be at particular risk for requiring prolonged mechanical ventilation. Aggressive management by the intensive care unit with protocols for early extubation and the use of non-invasive ventilation (BIPAP and NCPAP) have demonstrated benefits in the prevention of respiratory failure [11, 12]. Pre-operative assessment by pulmonology to optimize pulmonary function before proceeding with surgery may also help minimize some of this risk.

The second most common complication reported in our study was wound related (9.7%). This is significantly higher than the published 1–2% rate seen in the AIS population [1, 13–16]. They were primarily deep wound infections but also included superficial infections, dehiscence, seroma, hematoma, and prolonged drainage; all required a reoperation. While the majority occurred in the perioperative period (6.2%), a significant portion was delayed (3.5%). Our rate of wound complications was similar to those already reported in the literature for CP scoliosis [6, 17, 18]. Sponseller et al. reported a 10% infection rate in a retrospective review of 157 CP patients treated for scoliosis [19]. They found higher preoperative white blood cell count and the use of unit rods to be risk factors for the development of a postoperative infection.

Medical complications occurred in 5.8% of patients and represent a diverse group of problems. They include: hypotension or shock, myocardial infarction, urinary tract infection, deep vein thrombosis and others. While difficult to analyze individually, grouped together they demonstrate the complexity of the postoperative care of the CP patient. Not routinely reported in the literature, major medical complications in the AIS population are exceedingly rare with a reported incidence of 0.06% in a recent publication<sup>1</sup>. Appropriate medical management by the ICU or medical specialists may be needed and in some cases outweigh the postoperative surgical management.

The most concerning complication reported in this study is the mortality following surgery. There were 11 deaths that occurred after the time of spine surgery, 4 of which occurred within 1 year. Only 2 of the deaths were known to be directly related to the spine surgery. One occurred 3 months post-operatively and included cerebral infarction due to acute hydrocephalus and *E. coli* meningitis. The other death was related to an infection 2 months after being treated for a wound infection. Very few reports exist on the mortality following spinal deformity surgery. Barsdorf et al. reported a 1.6% in-hospital mortality rate for pediatric patients undergoing correction of neuromuscular spinal deformity [20]. This rate, however, was not specific to the CP population. Tsirikos et al. reported a 1% perioperative mortality rate following spinal surgery in patients with CP [21]. This is similar to our rate of 0.8% that we found directly related to surgical treatment. The other important issue our findings open to consideration is the general survivorship of the CP patient that undergoes scoliosis. Approximately 4% of the 257 patients analyzed died following their surgery timing of which ranged from the perioperative period to 5 years postoperative. This was significantly lower than the 28% mortality rate Sitoula et al. found [22]. Their patients were younger at the time of surgery with a mean age of 8.3 years suggesting a more severe patient population.

## Conclusion

Spinal surgery for CP can have significant major complications. When preparing patients and their families, having an accurate understanding of complication rates following spinal fusion and instrumentation for CP is of great importance. In addition, many of these risks may be reduced by optimizing patients' overall health [23]. While a formal process has not been employed by this multicenter group, many centers will refer patients for pulmonary, nutritional and anesthetic assessment before any procedure is undertaken. In some cases, the risks of complications may be too extreme to consider pursuing a surgical intervention. With a major complication rate of 36% and a spine-related reoperation rate of 14%, future studies will be needed to better understand the risk and methods to mitigate these risks.

## Key Points

- In patients with CP undergoing spinal fusion and instrumentation for a spinal deformity, there was a major perioperative complication rate of 36% with a spine-related reoperation rate of 14%.
- Within the perioperative period, the major complication rate was 25% and the reoperation rate was 8.6%.

The majority of these complications were pulmonary (11%), wound (6%), or medical (4%) related.

- The rate of delayed major complications was 11%, which were primarily deep infections (3%) and instrumentation-related (2%).
- Spinal surgery for CP can have significant major complications and it is of great importance to have an accurate understanding of the complication rates when preparing patients and their families for the procedure.

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## Compliance with ethical standards

**Ethics approval** This study has been approved by the IRB.

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