Life expectancy in pediatric patients with cerebral palsy and neuromuscular scoliosis who underwent spinal fusion

Athanasios I Tsirikos MD, Department of Orthopaedics, University of Athens, KAT Hospital, Athens, Greece.
Wei-Ning Chang MD, Department of Orthopaedics, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan.
Kirk W Dabney MD;
Freeman Miller* MD, Department of Orthopaedics, Alfred I duPont Hospital for Children, Wilmington;
Joseph Glutting PhD, University of Delaware, Newark, Delaware, USA.

**Correspondence to fourth author at* Department of Orthopaedics, Alfred I duPont Hospital for Children, PO Box 269, Wilmington, DE 19899, USA.
E-mail: fmiller@nemours.org

The aim of this study was to document the rate of survival among 288 severely affected pediatric patients (154 females, 134 males) with spasticity and neuromuscular scoliosis who underwent spinal fusion (mean age at surgery 13 years 11 months, SD 3 years 4 months), and to identify exposure variables that could significantly predict survival times. Kaplan–Meier survival analysis was performed demonstrating a mean predicted survival of 11 years 2 months after spinal surgery for this group of globally involved children with cerebral palsy (CP). Cox's proportional hazards model was used to evaluate predictive efficacy of exposure variables, such as sex, age at surgery, level of ambulation, cognitive ability, degree of coronal and sagittal plane spinal deformity, intraoperative blood loss, surgical time, days in hospital, and days in the intensive care unit. Number of days in intensive care unit after surgery and the presence of severe preoperative thoracic hyperkyphosis were the only factors affecting survival rates. This demonstrated statistically significant predictability for decreased life expectancy after spinal fusion in children with CP.

The development of neuromuscular scoliosis in pediatric patients with cerebral palsy (CP) constitutes a frequent orthopaedic problem. Increased incidence is directly proportionate to the degree of neurological impairment and inversely proportionate to the level of ambulation (Bradford 1987, Bell et al. 1989, Rinsky 1990, Banta et al. 1999, Renshaw 2001, Herring 2002, Labelle and Grimard 2002). Scoliosis in this group of children with severe disability significantly decreases their sitting tolerance and causes pain from impingement of their pelvis against the thoracic wall on the concavity of the curve. This situation may eventually create cardiopulmonary complications, particularly when the curve magnitude is such that individuals can barely spend any time in the erect or sitting position (Lipton et al. 1999). Spinal fusion is indicated in children with progressive scoliosis deformity, magnitude, and stiffness that interferes with their overall level of function (Renshaw 2001, Herring 2002, Labelle and Grimard 2002). Spinal surgery in patients with severe neurological involvement and complex general medical problems, often including respiratory dysfunction, poor nutritional status, severe feeding disorders, recurrent seizures, urinary tract infections, immunodeficiency, and coagulopathies, is associated with an increased risk of life-threatening complications. However, there is a positive impact on children by correcting the scoliotic deformity and maintaining a good coronal and sagittal spinal alignment. Spinal fusion, even in the more severely affected pediatric patients with CP, has a documented high satisfaction rate among parents/caregivers who appreciate the benefits of this procedure, especially in the patients' sitting ability, physical appearance, ease of care, and comfort (Comstock et al. 1998).

CP is probably the most common neurological disease that causes permanent physical disability in childhood (Hutton et al. 1994, 2000), but there is limited information on the predicted survival rate for this group of patients (Nelson et al. 1994, Strauss et al. 1998) even though affected individuals are assumed to have lower survival rates than the general population (Crichton et al. 1995). Life expectancy in patients with CP after the development of scoliotic deformities or after surgical correction of scoliosis has not been reported. The purpose of this study was to determine survival rates in children with severe disabilities due to spastic CP who developed neuromuscular scoliosis and underwent spinal fusion, and to define relative risk for different exposure variables that could potentially influence the outcome of long-term survival.

Method

Statistical analysis of survival rate was performed in a study cohort of 288 consecutive pediatric individuals with spastic CP and neuromuscular scoliosis who underwent spinal fusion at the Alfred I duPont Hospital, Delaware, USA between August 1988 and July 2000. This subgroup was derived from a total of 2677 patients who were followed closely in our CP program during the same period. The majority (70%) of the 288 patients included in our study were living in their family homes, whereas the remaining 30% lived permanently in residential homes. All patients, regardless of their residential status, were under the everyday care of health and educational professional caregivers who specialized in the treatment of children with CP and severe disabilities. They were also followed intensively at the outpatient clinic and other multidisciplinary clinics in our hospital, before and after the spinal surgery, in intervals that varied between 6 and 12 months. The aim was to ascertain that

a uniform postoperative management protocol and adequate level of care would be provided to all patients.

Our study group comprised 283 patients (154 females, 134 males; mean age at surgery of 13 years 11 months, SD 3 years 4 months) with quadriplegic and five patients with diplegic CP. Ambulatory status of the participants included 250 who were non-ambulators, 14 who could stand for assisted transfers, and 24 patients who were ambulatory. The vast majority of these patients (n=228) had profound mental retardation*, 26 patients had moderate mental retardation, and 34 patients had cognitive abilities close to normal.

All participants included in this study had severe neuromuscular scoliosis that was surgically corrected. The indication for surgery was scoliosis curve greater than 45° at the end of growth or a scoliosis causing seating problems before completion of growth. During this study period, only three children were felt to be too compromised to tolerate surgery and all three died within 18 months of the orthopedic evaluation. There were also five deaths of children who were scheduled for spinal surgery but who died before the surgery day. There were four families who elected not to have the surgery and allowed the child to become a bed patient. Two of these children died as the families elected comfort-care only. These 10 deaths are not included in the statistical analysis of this paper. The scoliotic deformity in the patients was associated with pelvic obliquity and, occasionally, sagittal spinal malalignment leading to significant frontal and lateral plane trunk imbalance. A consistent perioperative treatment protocol was applied to all of these patients. Thorough preoperative assessment and monitoring of the patients was performed, including evaluation of their respiratory capacity, cardiac function, immune system, coagulation mechanisms, nutritional status, feeding disorders, seizures, urinary system, and their overall level of functional impairment. The patients received postoperative hyperalimentation, prophylactic antibiotic treatment with the administration of a first-generation cephalosporin immediately before and for the first 24 hours after surgery, and homologous blood transfusions during the operation and in the postoperative period. After anesthesia induction, arterial and central venous lines were placed. A nasogastric tube was used to decompress the stomach and a Foley catheter was used to monitor urinary output. Cell-saver was not used intraoperatively.

Posterior spinal fusion was performed in 242 patients, whereas combined anteroposterior fusion was required in 46 patients with the aim of correcting more rigid deformities. In 31 of the 46 patients the anterior–posterior spine procedures were performed in one stage, and in two stages in the remaining 15 patients. There was no patient selection criteria for same-day versus staged spine surgery. All participants who received spinal fusion in the period between 1988 to 1991 were operated on in two stages. From early 1992 until July 2000 all combined anteroposterior spine operations were performed in one stage. The two senior authors (FM, KWD) using the same surgical technique performed both anterior and posterior operative procedures in all patients. The anterior approach allowed for an extensive release of the anterior longitudinal ligament and complete annulectomy and discectomy, with the intention to provide angular and rotational mobility of the spinal segments while at the same time enhancing anterior fusion in the excised disc spaces with the application of morselized rib graft. No anterior instrumentation was used. The unit rod instrumentation was applied in all patients to provide stable segmental posterior fixation, and abundant spinous process autograft with freeze-dried granulated cortico-cancellous allograft bone was applied to enhance spinal arthrodesis. Spinal cord monitoring with the use of somatosensory or motor-evoked potentials was applied during surgery in the ambulatory patients only. All of the patients were transferred postoperatively to the intensive care unit (ICU) where vigorous cardiopulmonary care and nutritional support were initiated.

A thorough review of the patients' medical charts and radiographs was performed with approval of the Institutional Review Board, focusing on the parameters that could theoretically affect the outcome and predict life expectancy after spinal fusion in this group of children with severe disabilities.

STATISTICAL ANALYSIS

The primary analysis used incidence rates with person–months survival as the follow-up parameter. Survival was examined according to the following exposure variables at the time of surgery: sex, age, level of ambulation, cognitive status, scoliosis angle, pelvic obliquity, thoracic kyphosis angle, lumbar lordosis angle, amount of blood loss during surgery, operative time, total days of hospitalization, and days in the ICU following surgery. We performed Kaplan–Meier survival analysis and calculated the 95% confidence interval (CI; Kaplan and Meier 1958). In addition, Cox's proportional hazards model was used to investigate predictive efficacy among simultaneous entry of the multiple exposure variables (Cox 1972). Relative risk was calculated for exposure variables found to predict significantly survival rate. All statistical comparisons were completed using SPSS for Windows (version 11.0). In addition, a power analysis was completed for the univariate relative risk comparisons versus the multivariate survival analysis because power would be lower for the univariate contrasts. Given a sample size of 288, an alpha level of 0.05, and assuming a medium effect size (i.e. w=0.30 as per Cohen 1988), power for the study was 0.99. Therefore, the power analysis indicated there was a 99% probability of finding differences in relative risk status if such differences truly existed in the population.

Results

Mean preoperative scoliosis angle in our study group was 74° (range 6 to 176°). Mean preoperative pelvic obliquity was 17° (range 0 to 57°). Mean preoperative kyphosis angle was 55.8° (range –44 to 130°; median ± 54.0°), varying from thoracic lordosis to hyperkyphosis. Mean preoperative lordosis angle was 38° (range –50 to 140°; median 38.0°), varying from lumbar kyphosis to hyperlordosis. Mean intraoperative blood loss was 2.8L (range 0.45 to 8L; median 2.5L), corresponding to 1.2 blood volumes. Mean surgical time was 4.4 hours, including both posterior-only and combined anteroposterior procedures (median 4 hours). Mean surgical time for the posterior-only procedures was 3.9 hours and 7.7 hours for the anteroposterior spinal fusions. Mean days of hospitalization were 19.6 (range 5 to 167 days). Mean number of days in the ICU was 5.2 (range 1 to 35 days). Table I presents means and standard deviations (SDs) for the variables listed above according to the survival group (survived versus did not survive).

Feeding through gastrointestinal tubes was necessitated in almost half of the patients. Gastrostomy or jejunostomy

*UK usage: learning disability.

tubes were present in 80% of the patients who died. The majority of patients were under anticonvulsant medication therapy to control severe intractable seizures, and many had a long history of urinary tract and respiratory infections. Children with persistent gastroesophageal reflux and frequent pulmonary infections had Nissen fundoplication in order to reduce the incidence of aspiration pneumonia. Fundoplication was performed after the scoliosis correction if reflux remained a problem. We have not found a direct correlation between complications and the presence of reflux when the reflux is under adequate medical management (Lipton et al. 1999).

Of the 288 patients who required spinal realignment procedures, 36 (12.5%) died. Three patients died perioperatively; whereas the mean survival rate for the remaining 33 patients was 4.3 years (range 2 months to 11 years 5 months). Six patients died less than a year after surgery, 10 patients between 2 and 5 years, 15 patients died between 5 and 10 years postsurgery, and 2 patients died more than 10 years from the time of the spinal fusion. Death occurred between ages 5 and 10 years in two children, between 10 and 15 years in seven children, between 15 and 20 years in 16 children, and over 20 years of age in 11 individuals. Cause of death was undetermined in most of the patients (Table II). The etiology of death could not be identified in 25 children; five of these patients were found dead in bed by their caregivers. Complications related to respiratory function were the cause of mortality in four patients. Septic and hypovolemic shock, pancreatitis, coagulopathy, intestinal complications, electrolyte disorders, and dehydration were responsible for death in the remaining seven patients. Two of the three patients who died in the perioperative period did not receive cardiopulmonary resuscitation upon request of the parents.

Kaplan–Meier statistical analysis demonstrated that the mean survival for this group of pediatric patients with spastic CP and severe involvement who underwent spinal fusion was 11.2 years with the 95%CI varying from 125.8 to 142.4 months (Fig. 1). Outcomes from the proportional hazards regression analysis showed that two exposure variables significantly predicted survival times: degree of preoperative thoracic kyphosis angle and length of ICU stay following spinal surgery, as determined by beta coefficients (ß), Wald statistics, and significance levels for the analysis (Table III). No other exposure variable was significantly associated with survival time.

Relative risk was assessed for each significant predictor. Relative risk has a clear intuitive meaning. As values of relative risk progress beyond 1.0, patients at each successive degree of kyphosis have an increased risk for death after spine surgery. This risk becomes particularly significant for patients with excessive thoracic kyphosis. As relative risk successively descends below 1.0, patients at each degree of kyphosis become less at-risk for death. Last, when relative risk equals 1.0, children with CP and this degree of kyphosis are at the mean chance rate for death when undergoing spinal arthrodesis (Fig. 2).

Relative risk was also determined for the number of days in the ICU (Fig. 3). The same steps as for kyphosis were followed to calculate the relative risk associated with the number of days in the ICU using the appropriate ß weight (see Table III). For example, if a child was in the ICU for 5 days, the relative risk equals 1.51. Therefore, this child is 1.51 times more likely to die than a child who would not require a stay in the ICU after the spinal surgery. However, all the children included in our

Table I: Means (SDs) by group of exposure variables

Variables	*Groups*			
	Survived		*Did not survive*	
	Mean	*SD*	*Mean*	*SD*
Preoperative kyphosis angle	54.3	29.4	68.3	30.8
Preoperative lordosis angle	38.8	32.2	30.5	29.5
Interoperative blood loss	2.9	2.4	2.9	1.6
Surgical time	4.4	1.5	4.6	1.4
Length of stay in ICU	5.1	5.3	6.4	5.0
Sex	Males	Females	Males	Females
	115	136	19	17

Table II: Etiology of death among patients who underwent spinal fusion

Cause of death	*n*
Septic shock	2
Hypovolemic shock (perioperative death)	1
Acute hemorrhagic pancreatitis (perioperative death)	1
Acidosis/dehydration	1
Acute coagulopathy (perioperative death)	1
Meckel diverticulum	1
Pneumonia	1
Chronic pulmonary failure	1
Eroded trachea/uncontrollable bleeding	1
Occluded tracheal diversion	1
Found dead in bed	5
Unknown	20
Total	36

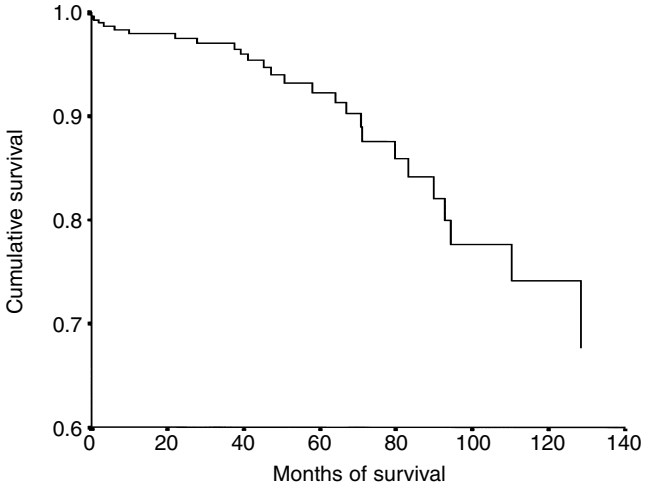

Figure 1: *Survival function at mean of covariates for 140 months. 1.0=100%.*

study spent at least 1 day in the ICU. Consequently, all children were subject to some risk but the relative risk increased dramatically with longer ICU stays.

Discussion

CP has been defined as a permanent disorder involving both movement and posture, with evolving clinical manifestations, that appears early in life as the result of a static lesion affecting the immature brain (Little Club 1959). Previous epidemiological studies had reported a relatively high mortality rate among patients with CP compared with that of the general population (Eyman et al. 1990, 1993). However, more recent studies have documented substantially better survival rates, clearly demonstrating that with the intense current medical support provided by the modern health systems, CP should be considered a disease with which one lives in contrast to the old belief that it is a condition from which one dies (Evans et al. 1990; Hutton et al. 1994, 2000; Plioplys et al. 1998). Kudrjavcev et al. (1985) reported on a group of 64 children with CP up to 10 years of age who showed a 10% mortality rate within the first 10 years of life, with all of the patients who died having severe disabilities. Von Wendt et al. (1985) studied a group of 69 children with CP and reported a 19% mortality rate by the age of 14 years. Evans et al. (1990) documented a 90% survival rate among 732 pediatric patients from a regional registry of children with CP. Eighty percent of the patients with quadriplegia survived for 10 years suggesting that most, even of the most severely involved children, attain adulthood. Crichton et al. (1995) analyzed the data from the CP registry in British Columbia, Canada, and reported a mean 30-year survival rate of at least 87%, varying from 95% in patients with hemiplegia or monoplegia to 83.5% in those with quadriplegia having the worst prognosis.

The most significant determinants for reduced life expectancy in pediatric patients with CP are the coexistence of other significant disorders such as respiratory malfunction, epilepsy, feeding disorders (particularly in patients requiring gastrostomy or nasogastric tube feedings), the degree of neurological involvement, the presence of severe cognitive abnormality, and the level of ambulatory disability (Evans et al. 1990; Eyman et al. 1990, 1993; Hutton et al. 1994, 2000; Crichton et al. 1995; Anderson 1996; Plioplys et al. 1998; Strauss et al. 1998). Respiratory disease, especially pulmonary infection, seems to be the predominant cause of death, specifically among individuals with mental retardation (Tarjan et al. 1968, Chaney et al. 1979, Eyman et al. 1990). However, for most of the patients in our study group (69.4%) the etiology of death was unknown, and only 11% of these children developed lethal complications known to be related to their respiratory function.

Our study focused on determining survival rates after a relatively common orthopaedic procedure in pediatric patients with CP and spasticity, almost all of whom had severe neurological impairment with comorbidities. Spinal surgery

Table III: Proportional hazards outcomes for statistically significant predictors of survival

Predictor	*ß*	*95% Confidence Limit of ß*		*Wald statistic*	*df*	*p*[a]
		Lower	*Upper*			
Degree of kyphosis at time of surgery	0.016	0.002	1.030	5.169	1	0.023
Number of days in intensive care unit	0.083	0.028	1.149	8.588	1	0.003

ß, beta coefficient; [a]$p < 0.05$ considered significant.

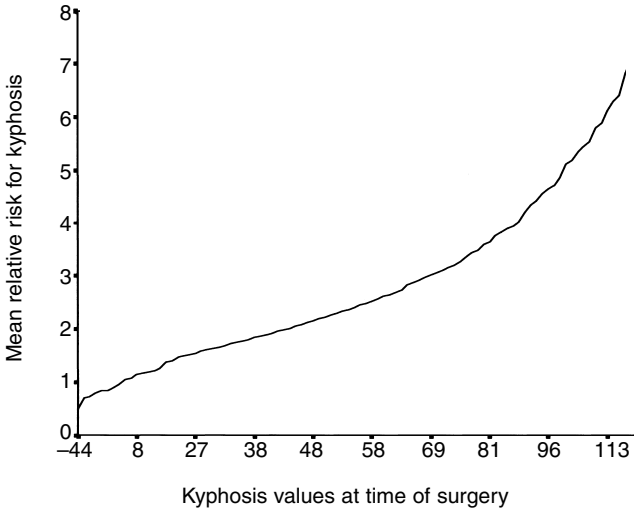

Figure 2: *Mean relative risk of death related to thoracic kyphosis at the time of surgery.*

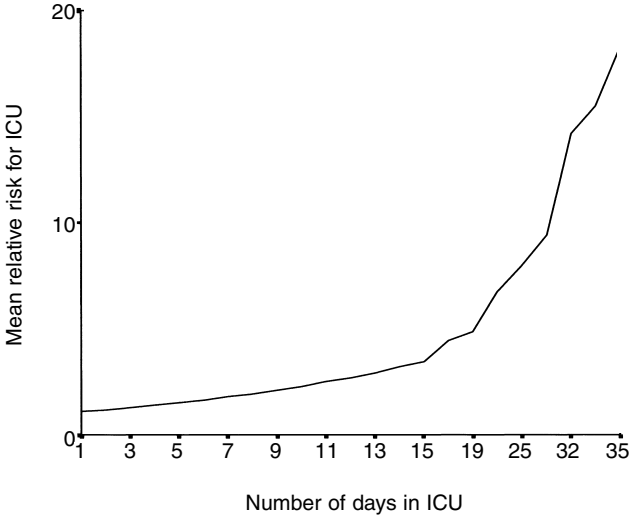

Figure 3: *Mean relative risk of death related to number of days in intensive care unit (ICU).*

in this group of patients, even in the more severely involved children with quadriplegia, is associated with high satisfaction among caregivers who perceive an overall improvement in the children's quality of life. Although the patients in our group had severe impairments they demonstrated a mean survival of 11 years 2 months. It is important to note that our study covers a relatively recent period reflecting improved and very intense medical management of children and adolescents with CP which probably accounts for the better longevity outcomes than some of the older studies.

The different exposure variables that were included in our statistical study were analyzed separately to define their significance in predicting life expectancy. Results demonstrated the presence of thoracic hyperkyphosis, and therefore sagittal plane malalignment at the time of surgery, as a significant predictor of survival. The greatest asset of relative risk is that it offers practical applications. Two steps are necessary to calculate the relative risk associated with a specific degree of kyphosis. First, take the degree of kyphosis and multiply it by the beta weight (i.e. 0.016, as shown in Table III). Second, take the product and calculate its exponent, which yields the relative risk. For example, if we assume that a child has a thoracic kyphosis of 85.6°, which is one SD above the mean preoperative kyphosis angle of 55.8° for this group of patients (Table IV), the relative risk equals 1.6. Thus, a child with CP and thoracic kyphosis of 85.6° is 61% more likely to die after spinal fusion than a child with a kyphosis value at the mean. Also, a child with a kyphosis value of 55.8° (mean value for our study group) is 61% more likely to die than a child with a kyphosis value of 26°, which is a value one SD below the mean. Accordingly, the child with a kyphosis angle one SD above the mean (85.6°) is 122% more likely to die than a child with a kyphosis value one SD below the mean (26°).

Our observation that the preoperative degree of scoliotic deformity was not correlated statistically with survival rates was contrary to intuition. The most reasonable explanation for this apparent contradiction is that the smaller numeric range of the scoliosis leads to little data spread, whereas the kyphotic curves vary over a larger range. There may be other factors associated with the specific deformity that impact the cardiorespiratory system which are not understood. However, in this study we could not correlate the increased degree of kyphosis with recognized preoperative cardiopulmonary problems. Moreover, we did not encounter specific difficulties during the surgical correction in patients with complex deformities, including thoracic hyperkyphosis, compared with those with normal sagittal balance and isolated scoliosis. The days spent in the ICU appeared to be the most accurate predictive factor for the long-term survival rate of severely affected children and adolescents with spastic pattern CP. For example, a child who required 30 days of postoperative ICU care had a 10 times higher risk than a child who is in the ICU for 5 days. The length of ICU stay reflects, at least partially, the preoperative general medical status of each patient, particularly related to impaired respiratory function. Respiratory factors that tend to lead to long-term ICU stays are poor oral motor airway control, chronic aspiration, and progressive pulmonary changes as a result of persistent aspiration. However, when the children are evaluated preoperatively, we have not been able to predict accurately which children will have a prolonged ICU stay and, therefore, which children will be at significant increased risk of mortality (Lipton 1999).

Table IV: Mean values, median, and SD for preoperative kyphosis angle and postoperative days in intensive care unit

Mean/median/SD	*Kyphosis (°)*	*Length of stay in ICU (d)*
Mean values	55.8	5.2
Median values	54.0	3.5
SD	29.8	5.3

Exposure variables such as patients' sex, age at surgery, ambulatory and cognitive status, pelvic obliquity, lumbar lordosis angle, intraoperative blood loss, surgical time, and total number of days in the hospital did not demonstrate statistically significant predictability for life expectancy after spinal fusion in pediatric patients with spasticity. Some of these variables, such as ambulatory and cognitive ability, which were not found to be significant predictors for survival, are heavily influenced by the very small numbers of ambulatory children and the very few individuals with high level cognitive function in our study group. Based on previous studies (Evans et al. 1990; Crichton et al. 1995; Eyman et al. 1990, 1993; Hutton et al. 1994, 2000; Plioplys et al. 1998; Strauss et al. 1998), large populations that include more high-functioning individuals demonstrate these as significant factors. However, few of these less involved patients develop severe scoliosis.

In conclusion, our study demonstrated a relatively long mean predicted survival for children and adolescents with severe spastic CP and neuromuscular scoliosis who underwent spinal surgery, which is consistent with the current concept of increased life expectancy even for the patients with total-body involvement. The most accurate determinants for survival rates among this population group were the number of days the patient had to spend postoperatively in the ICU and the presence of excessive thoracic hyperkyphosis. Predicting life expectancy for children and adolescents with CP is difficult. However, parents should be counseled about prognosis. A similar group of severely affected children with CP who developed scoliosis in the surgical range and did not undergo spinal fusion was not available to us. Moreover, there are no historical data indicating survival rates in patients with CP and scoliosis who have not been operated on. Therefore, we are unable to make any assessment of the impact of the surgical correction on a child's life expectancy.

DOI: 10.1017/S0012162203001269

Accepted for publication 23rd May 2003.

References

Anderson TW. (1996) Life expectancy in cerebral palsy. *Lancet* **348:** 1516.

Banta JV, Drummond DS, Ferguson RL. (1999) The treatment of neuromuscular scoliosis. In: *AAOS Instructional Course Lectures* **48:** 551–561.

Bell DF, Moseley CF, Koreska J. (1989) Unit rod segmental spinal instrumentation in the management of patients with progressive neuromuscular spinal deformity. *Spine* **14:** 1301–1307.

Bradford DS. (1987) Neuromuscular spinal deformity. In: Bradford DS, editor. *Moe's Textbook of Scoliosis and Other Spinal Deformities.* Philadelphia: WB Saunders. p 271–305.

Chaney RH, Eyman RK, Miller CR. (1979) Comparison of respiratory mortality in the profoundly mentally retarded and in the less retarded. *J Mental Defic Res* **23:** 1–7.

Cohen J. (1988) *Statistical Power Analysis for the Behavioral Sciences,* 2nd edn. Hillsdale, NJ: Lawrence Erlbaum Associates.
Comstock CP, Leach J, Wenger DR. (1998) Scoliosis in total-body-involvement cerebral palsy. Analysis of surgical treatment and patient and caregiver satisfaction. *Spine* **23:** 1412–1424.
Cox DR. (1972) Regression models and life-tables. *J R Stat Soc Series B* **34:** 187–220.
Crichton JU, Mackinnon M, White CP. (1995) The life expectancy of persons with cerebral palsy. *Dev Med Child Neurol* **37:** 567–576.
Evans PM, Evans SJ, Alberman E. (1990) Cerebral palsy: why we must plan for survival. *Arch Dis Childhood* **65:** 1329–1333.
Eyman RK, Grossman HJ, Chaney RH, Call TL. (1990) The life expectancy of profoundly handicapped people with mental retardation. *N Engl J Med* **323:** 584–589.
Eyman RK, Grossman HJ, Chaney RH, Call TL. (1993) Survival of profoundly disabled people with severe mental retardation. *Am J Dis Child* **147:** 329–336.
Herring JA. (2002) Disorders of the brain. In: Herring JA, editor. *Tachjian's Pediatric Orthopaedics.* Philadelphia: WB Saunders. p 1121–1248.
Hutton JL, Cooke T, Pharoah PO. (1994) Life expectancy in children with cerebral palsy. *BMJ* **309:** 431–435.
Hutton JL, Colver AF, Mackie PC. (2000) Effect of severity of disability on survival in northeast England cerebral palsy cohort. *Arch Dis Child* **83:** 468–474.
Kaplan EL, Meier P. (1958) Nonparametric estimation from incomplete observations. *J Am Stat Assoc* **53:** 457–481.
Kudrjavcev T, Schoenberg BS, Kurland LT, Groover RV. (1985) Cerebral palsy: survival rates, associated handicaps and distribution by clinical subtype (Rochester, MN, 1950–1976). *Neurology* **35:** 900–903.
Labelle H, Grimard G. (2002) Pediatric spine. In: Koval KJ, editor. *Orthopaedic Knowledge Update 7: Home Study Syllabus.* Rosemont, IL: American Academy of Orthopaedic Surgeons. p 581–592.
Lipton GE, Miller F, Dabney KW, Altiok H, Bachrach SJ. (1999) Factors predicting postoperative complications following spinal fusions in children with cerebral palsy. *J Spin Disord* **12:** 197–205.
Little Club. (1959) Memorandum on terminology and classification of 'cerebral palsy.' *Cereb Palsy Bull* **1:** 27–35.
Nelson KB, Swaiman KF, Russman BS. (1994) Cerebral Palsy. In: Swaiman KF, editor. *Pediatric Neurology*, Vol 1. St Louis: Mosby. p 471–488.
Plioplys AV, Kasnicka I, Lewis S, Moller D. (1998) Survival rates among children with severe neurologic disabilities. *South Med J* **91:** 161–172.
Renshaw TS. (2001) Cerebral palsy. In: Morrissy RT, Weinstein SL, editors. *Lovell and Winter's Pediatric Orthopaedics.* Philadelphia: Lippincott Williams & Wilkins. p 563–599.
Rinsky LA. (1990) Surgery of spinal deformity in cerebral palsy. Twelve years in the evolution of scoliosis management. *Clin Orthop* **253:** 100–109.
Strauss DJ, Shavelle RM, Anderson TW. (1998) Life expectancy of children with cerebral palsy. *Pediatr Neurol* **18:** 143–149.
Tarjan G, Brooke CE, Eyman RK, Suyeyasu A, Miller CR. (1968) Mortality and cause of death in a hospital for the mentally retarded. *Am J Public Health Nations Health* **58:** 1891–1900.
Von Wendt L, Rantakallio P, Saukkonen P, Tviski M, Makinen H. (1985) Cerebral palsy and additional handicaps in a 1-year birth cohort from northern Finland–A prospective follow-up study to the age of 14 years. *Ann Clin Res* **17:** 156–161.