Changes in the Prevalence of Cerebral Palsy for Children Born Very Prematurely Within a Population-Based Program Over 30 Years

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Cerebral palsy (CP) is a chronic disorder of movement or posture of cerebral origin, arising in early life and is not the result of a progressive disorder.¹ In Western countries, the overall prevalence of CP is reported to be about 2 per 1000 live births depending on the birth years studied: in Sweden, 1995-1998, 1.9 per 1000 live births; in Sweden, 1991-1994, 2.1 per 1000 live births; and in Australia, 1967-1985, 2 to 2.5 per 1000 live births.¹ For births in 1985-1988 in Alberta, the reported prevalence was 2.6 per 1000 neonatal survivors.⁵

Among preterm children, Himmelmann et al² gave a gestational age–specific prevalence of 77 per 1000 live births for children born before 28 completed weeks' gestation in 1995-1998 in Sweden. Surman et al⁶ reported CP rates of 36 per 1000 live births for children of whose birth weight was less than 1000 g and who were born in the years 1993-1995 in the United Kingdom. Other reported and calculated CP prevalence rates for very premature and low-birth-weight infants suggest that rates vary from 40 to 152 per 1000 live births.⁴⁻⁷⁻¹⁰ Hospital-based CP prevalence rates range from 55 to 150 per 1000 admissions.¹⁷⁻²⁰

Because "an indicator of success in the prevention of CP (through perinatal care) would be a decrease in its prevalence,"¹¹ assessing trends of CP prevalence over time is of clinical importance. The key research question has been: "Are the CP prevalence rates, accounting for the improving survival rates, among extremely preterm infants increasing⁴⁻¹¹ or decreasing?"²⁶⁻²⁸ As Marlow²¹ described, however, constructing trends of disability rates, including those of CP, from various published reports on surviving preterm children is difficult. The main difficulty is the dependence of CP prevalence on population birth prevalence and secular trends.²⁶ For preterm children, Himmelmann et al² gave a gestational age–specific prevalence of 77 per 1000 live births for children born before 28 completed weeks' gestation in 1995-1998 in Sweden. Surman et al⁶ reported CP rates of 36 per 1000 live births for children of whose birth weight was less than 1000 g and who were born in the years 1993-1995 in the United Kingdom. Other reported and calculated CP prevalence rates for very premature and low-birth-weight infants suggest that rates vary from 40 to 152 per 1000 live births.⁴⁻⁷⁻¹⁰ Hospital-based CP prevalence rates range from 55 to 150 per 1000 admissions.¹⁷⁻²⁰

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**Context** Although cerebral palsy (CP) among extremely premature infants has been reported as a major morbidity outcome, there are difficulties comparing published CP rates from many sites over various birth years.

**Objective** To assess the changes in population-based, gestational age–specific prevalence rates of CP among extremely premature infants over 30 years.

**Design** Prospective population-based longitudinal outcome study.

**Setting and Participants** In Northern Alberta, 2318 infants 20 to 27 weeks’ gestational age with birth weights of 500 to 1249 g were liveborn from 1974 through 2003. By 2 years of age, 1437 (62%) had died, 23 (1%) were lost to follow-up, and 858 (37%) had received multidisciplinary neurodevelopmental assessment.

**Main Outcome Measure** Population-based prevalence rates of CP were determined. Logistic regression with linear spline was used to assess changes in CP prevalence over time.

**Results** At age 2 years, 122 (14.2%) of 858 survivors had CP. This diagnosis was confirmed for each child by age 3 years or older. Among those whose gestational age was 20 to 25 weeks, population-based survival increased from 4% to 31% (P < .001), while CP prevalence per 1000 live births increased monotonically from 0 to 110 until the years 1992-1994 (P < .001) and decreased thereafter to 22 in the years 2001-2003 (P < .001). Among those whose gestational age was 26 to 27 weeks, population-based survival increased from 23% to between 75% and 80% (P < .001), while CP prevalence per 1000 live births increased monotonically from 15 to 155 until the years 1992-1994 (P < .001) and then decreased to 16 in the years 2001-2003 (P < .001). For all survivors born in the years 2001-2003, CP prevalence was 19 per 1000 live births.

**Conclusion** Population-based CP prevalence rates for children whose gestational age was 20 to 27 weeks and whose birth weight ranged from 500 to 1249 g show steady reductions in the last decade with stable or reducing mortality, reversing trends prior to 1992-1994.

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children, using live births of the same gestational age as the denominator reduces selection bias and enhances comparability. Other reasons for the difficulty include the use of different birth years, gestational ages, incomplete follow-up, selection of study population by birth weight instead of gestational age, and reporting of rates among hospital survivors rather than gestational age-specific live births. Although publications to date give reports of 1 or more specific periods, none cover the full period from the time neonatologists have been able to successfully ventilate extremely premature infants.

This study aims to overcome these difficulties in comparing published CP prevalence rates by analyzing our prospectively collected data from a single population-based, well-developed system of care including referral, intensive care, and follow-up. Our goal was to assess changes in population-based, gestational age-specific prevalence rates of CP among extremely premature infants over 30 years.

**METHODS**

**Northern Alberta Referral, Intensive Care, and Follow-up System of Care**

More than 30 years ago, the Province of Alberta, Canada, with government-funded health care and universal access to care, developed 2 regional perinatal programs: north and south. From 1974 to 2003 the province’s population grew from 1.67 to 3.03 million residents while birth rates fell. The peak number of births, 45,097, occurred in 1983. Multiple-birth and premature-birth rates are increasing (Table 1). The policy across the province has been that all infants with birth weights of less than 1250 g are to be cared for within tertiary-level hospitals. Since 1974, all infants weighing less than 1250 g who were born in Northern Alberta and admitted to neonatal intensive care were prospectively enrolled in the follow-up cohort of the Northern Alberta Program and all parents of survivors were encouraged to attend multidisciplinary assessments. The nurse coordinator of the follow-up clinic visited the tertiary-level intensive care unit weekly to register infants and discuss follow-up with their families. Demographic information for each child including sex, born in a tertiary-level hospital or not, singleton or one of a multiple birth, type of birth (vaginal or cesarean delivery), birth weight, and gestational age were recorded.

Before the infant’s discharge from intensive care, a discussion was held with the parents and a letter was given to parents or guardians of each infant describing both the service and audit roles of neonatal follow-up and giving the approximate date of the first appointment. The long-term follow-up by developmental specialists and the availability of therapy, if needed, were described. Audit refers to trends in the mortality and neurodevelopmental morbidity outcomes in relation to intensive care. After giving oral consent, parents were invited to participate in the collection of grouped developmental outcomes of the infants to help to improve care in the future. Using this anonymous registry, the audit component has continuously been a strong focus of the follow-up part of this perinatal program.

For the purpose of this study, all live born infants whose gestational age was 20 to 27 weeks with birth weights of 500 to 1249 g and who were born in Northern Alberta of Albertan parents from August 1, 1974, through December 31, 2003, were eligible. Newborns with malformations were not included; this has been previously reported to be about 4% in this population of infants. Over 30 years, 124 infants weighing less than 500 g at birth were admitted to intensive care: 6 lived to be at least 3 years and 1 had CP of the nonambulatory type. The outcome of all births of neonates weighing less than 500 g at birth in Alberta for 1983-1994 has been previously reported.30

To account for all live births, information was prospectively extracted annually from records of the Reproductive Care Committee of the Alberta Medical Association. Compiled data on births from individual hospitals were obtained from these records. As previously described,28,31 these data are given by birth weight and gestational age.

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**Table 1. Background Population Statistics for 10 Birth-Year Periods of All Births to Provincial Residents Over 30 Years, 1974-2003**

<table>
<thead>
<tr>
<th>Birth, y</th>
<th>Provincial Population, Millions</th>
<th>Live Births for Provincial Residents</th>
<th>Live Births for Northern Regional Residents</th>
<th>Total Births per 1000 Population</th>
<th>One of Multiple Births, %</th>
<th>&lt;2500 g Birth Weight, %</th>
<th>&lt;37 Completed Weeks of Gestation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1976</td>
<td>1.919</td>
<td>32 118</td>
<td>18 628</td>
<td>17.8</td>
<td>1.8</td>
<td>6.5</td>
<td>6.6</td>
</tr>
<tr>
<td>1977-1979</td>
<td>2.006</td>
<td>35 985</td>
<td>20 442</td>
<td>17.9</td>
<td>1.9</td>
<td>6.4</td>
<td>7.0</td>
</tr>
<tr>
<td>1980-1982</td>
<td>2.165</td>
<td>40 022</td>
<td>23 213</td>
<td>18.4</td>
<td>1.8</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>1983-1985</td>
<td>2.340</td>
<td>40 006</td>
<td>26 448</td>
<td>18.9</td>
<td>1.8</td>
<td>5.4</td>
<td>6.4</td>
</tr>
<tr>
<td>1986-1988</td>
<td>2.372</td>
<td>42 223</td>
<td>25 575</td>
<td>19.9</td>
<td>2.0</td>
<td>5.9</td>
<td>6.8</td>
</tr>
<tr>
<td>1989-1991</td>
<td>2.463</td>
<td>42 979</td>
<td>24 496</td>
<td>17.7</td>
<td>2.1</td>
<td>5.7</td>
<td>6.6</td>
</tr>
<tr>
<td>1992-1994</td>
<td>2.573</td>
<td>40 491</td>
<td>23 060</td>
<td>15.7</td>
<td>2.3</td>
<td>5.6</td>
<td>6.6</td>
</tr>
<tr>
<td>1995-1997</td>
<td>2.649</td>
<td>37 515</td>
<td>20 805</td>
<td>14.2</td>
<td>2.8</td>
<td>6.0</td>
<td>6.9</td>
</tr>
<tr>
<td>1998-2000</td>
<td>2.810</td>
<td>37 328</td>
<td>22 346</td>
<td>13.4</td>
<td>3.1</td>
<td>6.0</td>
<td>7.9</td>
</tr>
<tr>
<td>2001-2003</td>
<td>2.979</td>
<td>38 455</td>
<td>23 272</td>
<td>12.9</td>
<td>4.2</td>
<td>6.3</td>
<td>8.5</td>
</tr>
</tbody>
</table>

*Adapted from Alberta Vital Statistics.*
age. The gestational age used is the best estimate of gestation available at birth recorded in completed weeks; from the mid 1980s, early second trimester fetal ultrasound guided gestational age determination. Using provincial data, birth weight for gestational age percentiles were calculated for all 1698 admissions to intensive care: those with a birth weight of less than the tenth percentile for gestational age were considered small for gestational age.

**Neonatal Follow-up Clinic: Assessment and Diagnosis of CP**

For the entire study period, the follow-up part of the Northern Alberta Perinatal Program was under the direction of the same neurodevelopmental pediatrician (C.M.T.R.) and located at the Glenrose Rehabilitation Hospital, Edmonton, Alberta. The multidisciplinary format of repeated assessments used in the program has been reported. From 1974 to 1980, all children were seen every 3 months; after 1980, assessments were conducted every 6 months with additional visits as required.

At the first follow-up visit, each child was seen by the physician, nurse, physical therapist, and audiologist and if delay or feeding difficulties were suspected, by an occupational therapist, dietitian, or both as necessary. If motor delay was present, these physical and occupational therapists became the treating therapists for the child, seeing the child as needed, or the child was referred to community therapists. Clinic reassessment for a delayed child occurred about every 3 months. All children including those with CP, other delayed children, and those not delayed were seen at 18- to 24-month adjusted age (2 years ±3 months’ chronological age) by the physician, nurse, psychologist, and speech language pathologist and, if needed, the physical therapist, occupational therapist, or audiologist. Participation in this comprehensive assessment was 97.4%. The outcome diagnoses from this assessment were recorded in an electronic database by the nurse coordinator with ongoing checks for accuracy by a data analyst. Updated diagnoses were similarly recorded at subsequent assessment ages. A total of 4 neurodevelopmental pediatricians and 2 neonatologists have been the physicians in this clinic since 1974. Thus, throughout 30 years, all diagnoses of CP were made by only 6 physicians, all which were reviewed by a single physician. In addition, throughout this 30-year period, all children with a diagnosis of CP have been seen by the same pediatric physiatrist (M-J.W.) and a consensus diagnosis of CP (spastic, dyskinetic, ataxic) and subtype (hemiplegic, diplegic, quadriplegic) made. Children with CP were transferred to the Physical Medicine Clinic (the CP treatment center for Northern Alberta) in the same hospital using the same charts. Outcomes of all children diagnosed with CP were confirmed (M-J.W.) after age 3 years and prospectively added to our database after a review of the reports or charts. The last child diagnosed with CP reached age 3 years in October 2006. Children with CP remain with this treatment clinic until they are 12 years old; children without CP were seen in the follow-up clinic up to varying ages over the 30 years.

The definition of CP used in the program has been a disorder of movement and posture due to a defect or lesion of the immature brain. Children were grouped, using outcomes collected from those older than 3 years, as (1) ambulatory, ie, capable of walking independently or without ankle-foot orthoses, assistive mobility devices, or both or (2) nonambulatory, ie, requiring transportation or power mobility devices. This latter group may include some children with less spasticity but associated severe mental delay or blindness leading to failure of ambulation.

**Ethics Approval**

Throughout the 30 years and while infants were in intensive care, parents were informed verbally and in writing about the service and audit components of follow-up. Upon the parents’ attendance at follow-up and in a letter accompanying each clinic visit report, the parents were thanked for their participation in the follow-up clinic including the audit component. An approval from the Health Research Ethics Board of the University of Alberta was obtained to perform secondary analysis of data from the existing database.

**Statistical Analysis**

All demographic and outcome data were stored in a database using SPSS, currently SPSS version 12.0 for Windows (SPSS Inc, Chicago, Ill). The numbers of live births were enumerated separately for those 20 to 25 weeks of gestation and 26 to 27 weeks of gestational age. Population-based mortality in each of the 2 gestational age groups was calculated by dividing the sum of the number not admitted to intensive care and the number who died in intensive care or before age 2 years by the total number of live births; hospital-based mortality was calculated by dividing the number of deaths before age 2 years by the number of intensive care admissions. The population-based prevalence rate of CP per 1000 live births for each gestational age group was calculated by dividing the number of CP cases by the total number of live births. Background descriptors of children with and without CP were compared using Fisher exact test or t test (all tests are 2-sided). To assess changes in CP prevalence over the 30 years for each gestational age period, logistic regression models were used with mid points of the 10 3-year periods as continuous covariates. A linear-spline function with a knot at 1993, the midpoint of a 3-year period at which the clear change in the CP prevalence was observed, was used as the covariate (ie, the slope of the linear line of log odds of CP was allowed to change at 1993):

\[
\logit \Pr(CP=Yes) = \beta_0 + \beta_1 \text{Year}/10 + \beta_2 (\text{Year} - 1993)/10
\]

where \(A \leftarrow \max(0, A)\). The parameter values of \(\beta_1\) and \((\beta_1 + \beta_2)\) represent the changes in log odds of CP over a 10-year period before 1993 and after 1993, respectively. Wald tests were
used for testing the null hypothesis of these parameter values being equal to 0. To adjust for multiple comparisons in selecting the knot at 1993, we used Bonferroni correction of inflating P values by a factor of 8 because there were 8 possible knot points with the 8 middle 3-year periods. In all statistical tests, P values (or adjusted P values) of .05 or smaller were considered to indicate statistical significance. Higher orders of spline functions were also considered, but the best statistical fit to the observed data was achieved by the linear spline with one knot. Graphic representations of the number of children with CP per 1000 gestational age–specific live births for each of the 10-year periods were drawn for each gestational age group. Statistical analyses were performed by R version 2.3.0.

RESULTS

Background Characteristics

During 1974-2003, our region had 2318 live births whose gestational ages ranged from 20 to 27 weeks and whose birth weights ranged from 500 to 1249 g, with 620 (27%) dying before they were admitted to intensive care; 1698 infants were admitted to tertiary-level intensive care. Of 2318 infants, 793 (34%) died in intensive care, 24 (1%) died within 2 years of discharge from intensive care, 23 (1%) were lost to follow-up primarily because of leaving the province, and 858 (37%) infants were assessed at age 2 years. Of the 1698 infants admitted to intensive care during the 30-year period, 929 (55%) were boys, 1423 (84%) were born at a tertiary-level hospital, 1356 (80%) were singleton births, 441 (26%) were delivered by cesarean, and 96 (6%) were small for gestational age. There was an increase over time of those born within the tertiary-level hospital (58% to 88%, P < .001) and by cesarean delivery (10% to 48%, P < .001; FIGURE 1).

Proportion of Survivors With CP

Of 858 children with follow-up records, 122 (14.2%) had confirmed CP, 121 with spastic CP (52 diplegic, 24 hemiplegic, 7 triplegic, and 38 quadriplegic) and 1 with ataxic CP. Of these 122 children, 46 had projected non-ambulatory CP (2 diplegic, 5 triplegic, 38 quadriplegic, and 1 ataxic). The only descriptive variable found to differ among those with CP and those without was gestational age with more CP among those less mature (TABLE 2). To be small for gestational age, to be born by cesarean delivery, or to be born of a multiple gestation pregnancy did not relate to CP (Table 2) for the entire cohort. Numbers were too small to be certain that these variables had no influence in any one specific period.

CP Prevalence Rates

Population-based survival increased from 12% to 51% over the 30 years for infants whose gestational age ranged from 20 through 27 weeks and whose birth weight ranged from 500 to 1249 g; hospital-based survival increased from 18% to 84% (TABLE 3). In 1974-1976, the prevalence rate of CP was 7 per 1000 live births, peaking in 1992-1994 at 131 per 1000 live births, and declining to 19 per 1000 live births in 2001-2003. Nonambulatory CP was not diagnosed for births during the years 1974-1977, but gradually increased, peaking in 1992-1994 at 59 per 1000 live births and declining in 2001-2003 to 8 per 1000 live births. For infants 20 through 25 weeks’ gestational age, the prevalence of CP parallels improved survival with a CP rate of 110 per 1000 live births in 1992-1994 and a subsequent plateau of survival and decrease in the CP rate to 22 per 1000 live births (FIGURE 2). For these infants, log odds of CP increased with a linear slope of 2.23 per 10 years before 1992-1994 (95% confidence interval, 1.27-3.19; P < .001) and decreased with a linear slope of −1.69 after 1992-1994 (95% confidence interval, −2.79 to −0.58; P = .003). Those 26 through 27 weeks’ gestational age follow a similar pattern with a CP rate of 155 per 1000 live births in 1992-1994 and a current prevalence of 16 per 1000 live births (FIGURE 2). For these slightly more ma...
ture infants, log odds of CP increased with a linear slope of 1.12 per 10 years before 1992-1994 (95% confidence interval, 0.57-1.68; \( P < .001 \)) and decreased with a linear slope of −1.79 after 1992-1994 (95% confidence interval, 2.79 to −0.78; \( P < .001 \)).

The prevalence of CP among hospital-based survivors in our study follows a pattern similar to that of the population-based data with CP rates peaking in 1992-1994 for those whose gestational age was 20 through 25 weeks was 13% (33%) of 39 survivors and for those whose gestational age ranged from 26 through 27 weeks was 20% (20%) of 80 survivors, by 2001-2003 these proportions decreased to 7% of 42 and 2% of 92 survivors, respectively.

**COMMENT**

**Prevalence Rates of CP**

The prevalence of CP in 2001-2003 of 19 per 1000 live births for more than 3-year-old survivors of extreme prematurity is, to our knowledge, the lowest reported to date in the literature. This study provides CP prevalence rates based on gestational age–specific live births for extremely preterm infants over a 30-year period from a large population-based perinatal program with consistency of referral and CP diagnosis. For both the gestational age–specific groups of 20 to 25 and 26 to 27 weeks, population-based survival increased until 1992-1994, the birth years of highest CP prevalence for this cohort. The increasing prevalence of CP parallels an increase in survival until that time. This link of survival and CP prevalence reflects clinical observations and concerns voiced in the literature.4,8,10,11,21 A study in Europe showed the prevalence rate of CP among those weighing less than 1500 g rose from the mid 1970s to the early 1990s from 39.4 to 95.5 per 1000 live births.38 Although that study38 includes children of greater gestational age than our cohort, the increase in prevalence over the same time period is similar to ours.

Our CP rates began to fall in 1995-1997, about the same birth time that a decrease was noted in Sweden.2 In contrast, a re-

### Table 2. Descriptive Variables of 858 Children 20 Through 27 Weeks’ Gestational Age and 500- to 1249-g Birth Weight With and Without Cerebral Palsy

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Cerebral Palsy (n = 736)</th>
<th>No (n = 122)</th>
<th>Yes (n = 614)</th>
<th>P Value†</th>
<th>Nonambulatory Cerebral Palsy (n = 46)</th>
<th>No (n = 812)</th>
<th>Yes (n = 34)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>367 (50)</td>
<td>66 (54)</td>
<td>.43</td>
<td></td>
<td>411 (51)</td>
<td>22 (48)</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>Inborn‡</td>
<td>641 (87)</td>
<td>103 (84)</td>
<td>.47</td>
<td></td>
<td>703 (87)</td>
<td>41 (89)</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>One of multiple births</td>
<td>117 (16)</td>
<td>17 (14)</td>
<td>.69</td>
<td></td>
<td>129 (16)</td>
<td>5 (11)</td>
<td>.53</td>
<td></td>
</tr>
<tr>
<td>Cesarean birth</td>
<td>271 (37)</td>
<td>34 (28)</td>
<td>.07</td>
<td></td>
<td>293 (36)</td>
<td>12 (26)</td>
<td>.21</td>
<td></td>
</tr>
<tr>
<td>Birth weight &lt;10% for gestational age§</td>
<td>32 (4.3)</td>
<td>3 (2.5)</td>
<td>.46</td>
<td></td>
<td>34 (4)</td>
<td>1 (2)</td>
<td>&gt;.99</td>
<td></td>
</tr>
<tr>
<td>Gestational age, mean (SD), wk</td>
<td>26.0 (1.1)</td>
<td>25.6 (1.3)</td>
<td>.008</td>
<td></td>
<td>25.9 (1.0)</td>
<td>25.6 (1.2)</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>Birth weight, mean (SD), g</td>
<td>883 (168)</td>
<td>864 (169)</td>
<td>.25</td>
<td></td>
<td>881 (168)</td>
<td>868 (167)</td>
<td>.61</td>
<td></td>
</tr>
</tbody>
</table>

*Data are presented as number (percentage) unless otherwise indicated.
†Fisher exact test or \( t \) test (all tests are 2-sided).
‡Being born at a tertiary-care hospital, thus, transportation to a neonatal intensive care unit was not required.
§Based on data from Robertson et al.31

### Table 3. Population-Based and Hospital-Based Survival of Children Born at 20 Through 27 Weeks’ Gestational Age Weighing 500 Through 1249 g Who Survived 2 Years and Prevalence of Cerebral Palsy at 3 Years or Older per 1000 Live Births for 881 Survivors

<table>
<thead>
<tr>
<th>Birth Year</th>
<th>No. of NIC Admissions (Total Live Births)</th>
<th>No. of 2-Year Survivors</th>
<th>Population-Based Survival, %</th>
<th>Hospital-Based Survival, %</th>
<th>No. With CP</th>
<th>Prevalence Rate of CP</th>
<th>No. With Nonambulatory CP</th>
<th>Prevalence Rate of Nonambulatory CP per 1000 Gestational Age-Specific Live Births</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1976</td>
<td>101 (149)</td>
<td>18</td>
<td>12</td>
<td>18</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1977-1979</td>
<td>124 (197)</td>
<td>27</td>
<td>14</td>
<td>22</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>1980-1982</td>
<td>173 (199)</td>
<td>41</td>
<td>21</td>
<td>24</td>
<td>5</td>
<td>25</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>1983-1985</td>
<td>178 (258)</td>
<td>76</td>
<td>29</td>
<td>43</td>
<td>15</td>
<td>89</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>1986-1988</td>
<td>154 (232)</td>
<td>79</td>
<td>34</td>
<td>51</td>
<td>10</td>
<td>43</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>1989-1991</td>
<td>263 (308)</td>
<td>134</td>
<td>44</td>
<td>51</td>
<td>21</td>
<td>68</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>1992-1994</td>
<td>198 (221)</td>
<td>119</td>
<td>54</td>
<td>60</td>
<td>29</td>
<td>131</td>
<td>13</td>
<td>59</td>
</tr>
<tr>
<td>1995-1997</td>
<td>149 (246)</td>
<td>103</td>
<td>42</td>
<td>69</td>
<td>17</td>
<td>69</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>1998-2000</td>
<td>190 (246)</td>
<td>150</td>
<td>61</td>
<td>75</td>
<td>17</td>
<td>69</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>2001-2003</td>
<td>159 (262)</td>
<td>134</td>
<td>51</td>
<td>84</td>
<td>5</td>
<td>19</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>1974-2003</td>
<td>1698 (2318)</td>
<td>881</td>
<td>38</td>
<td>52</td>
<td>122</td>
<td>53</td>
<td>46</td>
<td>20</td>
</tr>
</tbody>
</table>

Abbreviations: CP, cerebral palsy; NIC, neonatal intensive care.
*Twenty-three (2.6%) of 881 survivors were lost to follow-up by 2 years of age.
cent study from Eastern Canada for infants of 24 to 30 weeks’ gestational age showed an increasing population survival paralleled by increasing CP prevalence rates peaking at 175 per 1000 live births in 2001.11 That study linked improved survival and an increasing prevalence of CP.11 It should be noted that in the last year reported in that study, 2002, survival was 89% but CP rates dropped to 100 per 1000 live births.11

Because of significant differences in CP rates for different years and by gestational age-specific groups, we analyzed our data by gestational age groups that would allow comparison with the literature. Calculations from the EPI Cure Study Group data for 1995 births show the population-based survival of 33%, intensive care admission rate of 60%, hospital-based survival of 54%, and a CP prevalence rate of 57 per 1000 live births. Given the many differences in organization of care between the United Kingdom/Ireland and Western Canada, the CP rates are not remarkably different for that period.

Previously, we were able to show a prevalence rate of CP in our province of 2.6 per 1000 neonatal survivors.5 In that study including births from 1985-1988, low-birth-weight infants (<2500 g) accounted for 35% of all children with congenital CP. The proportion of CP usually associated with prematurity is about one half of cases.4,8 The cohort prevalence of CP for very-low-birth-weight (<1500 g) infants in Alberta in that study was 78.5 per 1000 neonatal survivors. Comparisons to the current population are difficult due to different groups (gestational age vs birth weight and different denominators). Major demographic changes have occurred in our provincial population since the birth years of that study, including a decrease in birth rate and increases in the rates of prematurity and multiple births. In spite of these changes, CP rates among the smallest infants have not risen. There is no other Canadian study for comparison.

**Possible Causes of Changes in CP Prevalence Rates**

A summary of systematic reviews of randomized clinical trials indicates that current evidence fails to support a reduction of CP by antenatal steroids, magnesium sulfate, thyroid hormone, surfactant, vitamin K, or phenobarbital.3 Our intensive care unit participated in the Exosurf (artificial surfactant) neonatal trial in 1988-199039 and in 1992-1996 was involved in an artificial vs bovine surfactant comparison trial.40 After 1996, bovine surfactant was used. We participated in the Indomethacin Prophylaxis Trial in 1996-199841 and conducted a randomized controlled trial, the Newborn Individualized Developmental Care and Assessment Program, from 1997 to 2000.42 The reduction in CP beginning in the mid 1990s may relate to a combination of the changes in care following these trials. The use of postnatal corticosteroids has also been associated with CP among low-birth-weight survivors.43 Since 2001, we have had a policy of requiring parental consent for their use based on guidelines.44 Some of the recent reduction in CP may be related to less postnatal corticosteroid use.

There has been no apparent change in the descriptive variables over the years that paralleled the changes seen in the CP rates. Infants delivered by cesarean did not have a lower rate of CP, while the proportion of small infants delivered operatively did increase over the study years.

For some time there has been concern that lower birth weight for gestational age was linked to greater CP rates.45 A recent study of 1983-1986 births showed that fetal growth restriction among preterms older than 28 weeks’ gestational age was associated with a reduced risk of CP.46 In the Eu-
CEREBRAL PALSY FOR VERY PREMATURELY BORN INFANTS

European CP study, only the expected number of 10% of those younger than 28 weeks’ gestational age were classified as small for gestational age. Overall, in our cohort, fewer than 6% of those admitted to intensive care had birth weight for gestational age of less than the 10th percentile compared with provincial standards, for 1983-1985, this percentage peaked at 16% of intensive care admissions and then decreased as overall survival improved. For our 122 children with CP and the 46 with nonambulatory CP, low birth weight for gestational age did not relate to the CP status. Preterm multiple births have been linked to CP. An increase in the proportion of multiple births among preterm infants is reflected in our population data. To be one of a multiple birth in this cohort, however, was not associated with CP.

The 1994 Joint Statement from the Canadian Pediatric Society and the Society of Obstetricians and Gynecologists of Canada recommending careful weighing of benefits and harm of aggressive care at 23 to 24 weeks’ gestational age may have impacted care. Although population-based survival rates have plateaued since 1992-1994, intensive care admission rates have dropped. At the start of our perinatal program, about half of live born infants of 20 to 25 weeks’ gestational age were admitted to intensive care. By 1992-1994, the peak period for CP, 85% of these infants received intensive care; 42% were admitted in 2001-2003. Similarly, for those 26 and 27 weeks’ gestational age, admission to intensive care increased from 87% in 1974-1976 to 95% in the peak years of CP prevalence, 1992-1994, decreasing to 81% in 2001-2003. Assessing whether the plateau of survival is related to a reduction in intensive care unit admissions of some infants treated more than a decade ago is outside the scope of this study. However, in this study, the highest CP rates were reached among population-based survivors of 26 and 27 weeks’ gestational age in 1992-1994, with rates of 155 per 1000 live births. This rate is higher than for infants of lower gestational age during the same period and is associated with high admission rates of 95% and survival of 78%. This trend in the early 1990s is consistent with the reports that increasing survival is associated with increased CP rates.

Limitations and Strengths

This study has several limitations. It is from 1 western Canadian province, and although the study is population-based, generalizability of the results remains limited. Examination of CP rates for single, specific gestational ages for each birth-year period was not possible due to the limited number of cases. While we chose to divide the 30 years into 10 3-year periods to make the rate estimate of each period sufficiently stable, this was a methodological compromise. Although we considered the use of 5-year periods, we hesitated because longer periods would be too long to reflect the many changes that occur in intensive care. Although we have previously published abnormal cranial ultrason data relative to CP, the lack of consistency of imaging over 30 years precludes such an analysis. Magnetic resonance imaging is now recommended for all children with CP. We have not attempted to change our diagnosis to match the new functional classification of CP released in 2005. Methods of making an early prognosis of ambulation have improved and presently are used in our clinic, but were not applied retrospectively to this cohort. Although the health records of the 5 lost children whose gestational ages were 25 weeks or fewer were reexamined to ensure that they had not been reffered to our CP center or to determine whether they may have died or had been diagnosed with CP outside our region, no children whose gestational age was 25 weeks or fewer were lost to follow-up in 2001-2003.

The strengths of this study are its population base with gestational age-specific live births, its consistently high follow-up rates, and its use of the same physician confirming the diagnosis and another physician managing all children with CP in Northern Alberta over this time. This study provides insight into the changing birth cohorts of extremely premature infants and the CP outcomes associated with these changes since the modern era of neonatology began.

Access to Data: Dr Robertson had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Author Contributions: Study concept and design: Robertson, Yasui. Analysis and interpretation of data: Robertson, Watt. Drafting of the manuscript: Robertson, Yasui. Critical revision of the manuscript for important intellectual content: Robertson, Watt, Yasui. Statistical analysis: Yasui. Administrative, technical, or material support: Robertson, Yasui. Determination of outcome variables: Robertson, Watt.

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CEREBRAL PALSY FOR VERY PREMATURELY BORN INFANTS


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