

The Child with Cerebral Palsy: Diagnosis and Beyond

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Cerebral palsy (CP) is one of the most common conditions we follow in our pediatric neurology offices. This review will hopefully convince you that the care of children with CP extends far beyond the diagnosis. The review addresses issues surrounding diagnosis, coimpairments, prognosis, and family-centeredness of care. It will also deal with routine office follow-up to prevent or identify complications, management of spasticity and other morbidities, alternative and complementary therapies, and finally transition.
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As child neurologists, we are often accused of embracing the “diagnose and adios” approach. In incurable conditions, such as cerebral palsy (CP), this has been particularly true. The purpose of this review is to present the many roles we have in the ongoing care and management of the child with CP. This starts with the diagnosis but extends far beyond. After the diagnosis, our roles include searching for an etiology, determining the presence of coimpairments, attempting to answer the parents’ questions about their child’s lifelong condition, and monitoring the child’s progress to be certain the child reaches their potential.

Diagnosis

CP is “an umbrella term covering a group of nonprogressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development.”¹ Central to the definition is nonprogression. At the initial presentation, many neurodegenerative conditions may have similar clinical features, particularly in infancy and early childhood.² When the child is first seen for diagnosis, the parents may not have appreciated the progressive nature of these conditions, and CP may be misdiagnosed. Progression will become obvious as the child is followed over time, which is the first reason not to “adios” after a diagnosis is given. Another reason for follow-up is that the motor impairments, on which the diagnosis was made, may resolve.

Nelson and Ellenberg³ reported on a cohort of children followed through the National Collaborative Perinatal Project. Over half of the children believed to have CP at age 1 year were free of any motor impairment on follow-up at 7 years. In view of this marked resolution of motor impairment, definitive diagnosis of CP is difficult before 1 to 2 years of age.

There are 2 very different clinical situations in which we diagnose CP. The first is in the setting of a child known to be at increased risk for CP and the second, and more difficult, is making the diagnosis in the absence of any known risk factors.

Infant at Risk

The incidence of CP is 1.5 to 2.5 per 1,000 live births.⁴ There are multiple perinatal factors that increase this risk.⁵ Common clinical situations include the premature infant with an abnormal cranial ultrasound, the term infant with presumed perinatal hypoxic-ischemic encephalopathy (HIE), and the infant with neonatal seizures and a cortical arterial infarct. All of these infants are at an increased risk for the development of CP, but how can we determine which infant will be affected (Table 1)?

Prematurity

Premature infants are at an increased risk of CP, and both the presence and grade of periventricular leukomalacia (PVL) increase that risk. A recent population-based prospective study found that 8.2% of children born between 22 and 32 weeks of gestation developed CP.⁶ The prevalence increased with decreasing gestational age, from 4% for infants born at

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Table 1 Factors Associated With Increased Risk for CP

Prematurity
Lower gestational age
Cystic PVL on serial neonatal ultrasounds
PVL on MRI at term
Background depression on early serial EEGs
Term birth asphyxia
Clinical signs of neonatal encephalopathy and/or seizures (Sarnat II/III)
Persistent abnormal background on serial EEGs
Persistent severe background abnormalities (flat, continuous low voltage, burst-suppression) on aEEG
Abnormal MRI, MRS, DW-MRI, ADC-MRI
Neonatal stroke
Abnormal neurologic examination at neonatal intensive care unit discharge
Factor V Leiden mutation
Elevated Factor VIIIc

32 weeks to 20% in infants born at <27 weeks. Regardless of gestation, 75% of infants with bilateral cystic PVL developed CP. It is important to note, however, that 4.4% of children with normal neonatal ultrasounds also developed CP. Therefore, because of the higher number of normal ultrasounds, 35% of premature infants who developed CP had normal neonatal ultrasounds.

Although we certainly need to follow premature infants with abnormal neonatal ultrasounds to detect CP, what should we do about the majority of preterm infants with normal neonatal ultrasounds? Magnetic resonance imaging (MRI) is difficult to perform on an ill neonate and is most useful at term, between 38 to 42 weeks, because the posterior limb of the internal capsule is myelinated after 37 weeks. Abnormalities in this area have been shown to correlate with the neurologic outcome for the premature infant. MRI is more sensitive than ultrasound for determining the extent of focal white-matter lesions, but studies vary in concluding whether MRI actually has a better predictive value for clinical outcome.⁷ A recent study did show that a single MRI at term had significantly better sensitivity than serial neonatal ultrasounds in predicting CP.⁸

Neonatal electroencephalogram (EEG) abnormalities have also been reported in premature infants who subsequently develop CP.⁹ By using serial EEGs, background depression on days 1 and 2 of life showed the highest correlation with development of CP. However, there is a very high false-positive rate. Even with the highest degree of EEG abnormality, only 50% went on to develop CP.

Currently, all very preterm infants (<32 weeks gestation) with abnormal neuroimaging should be considered as having a high risk for the development of CP. However, even infants at this gestation with normal imaging, ultrasound, or MRI have an increased risk compared with term infants. As the number of surviving premature babies increases, with the resultant rise in CP, this will become a major resource issue for child neurology.¹⁰ This is especially a concern with the increasing survival of extremely premature infants. Among infants <1,000 g, survival has increased from 49% to 67%

with the routine use of surfactant, but for every 18 additional infants surviving, 11 will have a neurodevelopmental disability.¹¹ Marlow and coworkers¹² recently reported on a cohort of infants born between 22 and 25 weeks gestation. No infant born at 22 weeks survived without impairment. The percentages of infants surviving without impairment at 23, 24 and 25 weeks were 1%, 3%, and 8%, respectively.

Term HIE

In the absence of other identifiable causes, HIE is often inferred as the cause for a child's CP. Neonatal encephalopathy, HIE, and intrapartum asphyxia are often used interchangeably, although they refer to different clinical situations.¹³ Neonatal encephalopathy describes the clinical state of the infant in the first 7 days of life. In 1976, Sarnat and Sarnat¹⁴ published a graded system (I-III) to describe infants with neonatal encephalopathy. The clinical features described were changes in tone, reflexes, poor state regulation, level of responsiveness/consciousness, and seizures. In addition to asphyxia, other conditions may present with many of the signs and symptoms of neonatal encephalopathy and may be confused with HIE. These include intrauterine infections, cerebral dysgenesis, and severe neuromuscular and metabolic disorders. Some of these conditions may also predispose the infant to asphyxia because the infant may already be neurologically compromised at delivery and will not tolerate the birth process. HIE specifically refers to a hypoxic/ischemic cause for the encephalopathy, usually assumed to have occurred intrapartum.

In the US National Collaborative Perinatal Project, 16% of the children with CP had a history of neonatal encephalopathy, with the triad of low Apgar scores, neonatal seizures, and abnormal neonatal signs (altered level of consciousness and altered tone).¹⁵ Infants with this triad had a marked increase in death, and over 50% of the survivors developed CP. A recent clinic-based study reported that 21.7% of children diagnosed with CP had asphyxia as a cause.¹⁶ A population-based study found that 24% of term infants with CP had had encephalopathy.¹⁷ In this study, 13% of survivors of neonatal encephalopathy developed CP. Thus, as with the premature infant, it is unclear which infants with asphyxia need to be followed after hospital discharge. Similarly, it is unclear how the parents of these children should be counseled. Infants with the triad of low Apgar scores, neonatal signs, and neonatal seizures are at the greatest risk of developing CP, but, even in this very high-risk group, almost half do not. In this situation, EEG and MRI have been more helpful.

The evolution of the interictal background, on serial EEG, is most helpful for predicting outcome. In 1 study that followed 38 term infants with acute fetal distress, the infants had 2 EEGs in the neonatal period.¹⁸ The first was recorded before 48 hours of age and the second between 2 and 7 days. When the early EEG was essentially normal, 13 of the 14 infants had a normal outcome, and in the 10 infants with a markedly abnormal early EEG, 5 died, 4 infants had severe sequelae, and 1 infant had a normal outcome. For the group with an early EEG showing intermediate abnormalities, the

change in background by age 7 days was most sensitive and specific for the later diagnosis of a poor outcome. When the background improved by the second EEG, 4 of these 5 infants had a good outcome. When the background stayed the same, or worsened, the remaining 9 infants all had poor neurodevelopmental outcomes.

Because standard EEGs are not routinely available in neonatal intensive care units, the use of continuous amplitude-integrated EEG (aEEG) is increasing. There are 5 patterns of background activity: flat tracing, continuous low voltage, burst suppression, discontinuous normal voltage, and continuous normal voltage. Asphyxiated term infants are more likely to have a poor outcome if they show the abnormal patterns of flat tracing, continuous low voltage, or burst suppression, especially if it is persistent.¹⁹ Of the 90 infants with these 3 abnormal amplitude-integrated EEG patterns at <6 hours of age, 79 died in the neonatal period or had moderate to severe disability by >2 years. Eleven survivors were neurodevelopmentally normal, and all had recovery of background activity to discontinuous or continuous normal voltage by 24 hours. Seven other infants also had recovery of their background activity but still had a poor outcome. For the 70 infants with early discontinuous or continuous normal voltage, 64 had a normal outcome.

Neuroimaging, especially MRI, can also be helpful to determine which infants are most at risk of CP after birth asphyxia. Barkovich et al²⁰ reported on 20 term infants with HIE who had MRIs within the first 10 days of life. Normal MRIs predicted normal outcome at 3 months of age in 4 of 4. The 16 infants with abnormal MRIs had changes in the thalami and basal ganglia, the cerebral cortex and subcortical white matter (particularly in the watershed areas), and the periventricular white matter, and several had a combination of abnormalities throughout all these areas. Five infants had a normal ultrasound within 24 hours of their abnormal MRI, suggesting that MRI is more sensitive. Five infants died, 10 had no clinical follow-up data, and 1 infant had hypertonica at age 3 months, with no further follow-up. This initial study confirmed that abnormalities in term asphyxiated newborns could be seen in the neonatal period. However, it is impossible to determine the clinical specificity of MRI from this study because the length of follow-up was too short.

Since then, there have been many reports of early MRI with clinical correlation. Barkovich et al²¹ has looked at the use of magnetic resonance spectroscopy (MRS). They reported on 31 infants with HIE; all had MRS between days 1 and 11 and were followed until 12 months of age. There was good correlation between MRS and neuromotor/cognitive outcome. The most sensitive predictor of a poor outcome was an elevated lactate/choline ratio. Particularly interesting in this report are 3 infants with elevated lactate/choline ratios in the watershed white-matter areas on their neonatal MRS. All 3 of these infants had abnormal motor examinations at age 3 months but were normal by 12 months. As discussed earlier in this review, it is important not to definitively diagnose CP before at least 1 year of age.

A more recent study compared standard MRI, diffusion-weighted MRI (DW-MRI), apparent diffusion coefficient of

water (ADC-MRI), and MRS in a group of 11 asphyxiated term newborns within 48 hours of birth.²² Two of the infants had completely normal imaging, with a normal neurodevelopmental outcome. None of the 9 infants with a poor outcome had normal imaging in all 3 modalities. However, none of the tests were reliably predictive. Apparent diffusion coefficient performed the worst, perhaps because these infants had edema involving the basal ganglia, which hindered imaging of the posterior limb of the internal capsule. As discussed earlier, this area has the best predictive value for CP. No infant had both a normal standard MRI and MRS. The authors recommended that infants should have a combination of studies to improve the early predication of outcome after term birth asphyxia.

Despite these technological advances, it is still very difficult to predict outcome for these infants. This ability is important clinically because we counsel families and allocate resources. It is also increasingly important scientifically to be able to accurately identify infants at increased risk of a poor outcome as research continues into neuroprotective agents (eg, drugs and hypothermia) to improve that outcome.

Neonatal Seizures and Cortical Infarct

The occurrence of neonatal stroke is estimated at 1 in 4,000 term births.²³ However, although some infants present at birth with seizures, others will present in the first year of life with hemiparesis. As well, not all infants presenting at birth with seizures caused by an infarct will develop CP. One study followed 46 term infants with a cortical infarct until 18 months of age.²⁴ Fifteen had no neurodevelopmental sequelae. The remainder had long-term disabilities. Twenty-two infants developed CP, many with associated cognitive impairment. Factors associated with a poor outcome were the presence of neonatal seizures and an abnormal neurological examination at discharge from the neonatal intensive care unit.

A population-based study identified 38 children with motor impairment who were born at term and had a CT or MRI that confirmed a cortical arterial infarct.²⁵ Twelve of the children presented in the neonatal period, all with seizures, and the remaining 26 presented in the first year of life, mainly with early handedness. The same group reported a case-control population-based study that included both preterm and full-term infants.²⁶ They reported a prevalence of perinatal arterial stroke at 20 per 100,000. Slightly more than half presented in the neonatal period, usually with neonatal seizures. Most infants were term. The preterm infants were diagnosed incidentally after routine ultrasound showed an abnormality that led to a CT. The authors selected 120 case controls for comparison for maternal, prepartum, intrapartum, and infant risk factors. The majority of infants had more than 1 risk factor, and a third had 4 or more risk factors. Many of the risk factors were associated, and, on multivariate analysis, only infertility, preeclampsia, chorioamnionitis,

prolonged rupture of membranes, and prolonged second stage of labor were significant.

Some risk factors, such as chorioamnionitis, may be mediated by inflammation. Inflammatory markers are elevated in the blood of newborns who develop CP. Nelson et al²⁷ analyzed dried newborn blood spots and reported that newborns who later developed CP had increased levels of interleukin 1, 6, 8, and 13 and tumor necrosis factor α . They also found that those infants were much more likely to have antiphospholipid antibodies, increased levels of factor V Leiden mutation, protein C, and often protein S antigens. Other studies have confirmed the relationship between stroke and factor V Leiden mutations.^{28,29} Approximately one half of the newborns presenting with seizures and stroke will go on to develop CP, usually hemiparetic. The presence of thrombophilias, especially factor V Leiden mutation, may increase that risk. For now, as with the other neonatal high-risk situations, we need to follow all of these infants because we cannot accurately predict which infant will develop CP. The mothers of babies with thrombophilia also require counseling regarding recurrence risk in further pregnancies.

Diagnosis in the Absence of Known Risk Factors

The diagnosis of CP is clinical, requiring that the child have nonprogressive motor impairment, with abnormalities in tone or posture, resulting from cerebral (ie, not neural tube or muscle) dysfunction, arising from early in development (usually defined as less than age 2 years) and therefore does not require any investigations. The role of investigations in children with CP is to help in determining the etiology and in assessing for coimpairments.

Investigations: Etiology

Investigations will always be required when CP is diagnosed in a child without any known risk factors. Investigations may also be necessary even when a child at risk of CP is diagnosed. Shevell et al¹⁶ reported on 217 cases of CP. For the 82% that had an identified cause, there was usually a single apparent etiology; however, in 34 cases, there were multiple etiologies, such as asphyxia and cerebral dysgenesis. All the children had neuroimaging. The 5 major etiologies were PVL, asphyxia, cerebral dysgenesis, intracranial hemorrhage, and infarcts. Less common causes were infection, trauma, cerebral atrophy, or toxins. The Surveillance of Cerebral Palsy in Europe collaboration looked at CP of postneonatal origin.³⁰ They were able to identify an etiology for 99% of the cases. Fifty percent were attributed to infection, predominantly meningitis and encephalitis. Other causes were vascular, trauma, and a collection of less common causes such as near-miss sudden infant death syndrome and near drowning.

Investigations are targeted to the most likely etiology for a particular child. A child with spastic diplegia, born at 28 weeks gestation, most likely has PVL. Even if the child had a normal neonatal head ultrasound, it is still reasonable to perform an MRI. The MRI is more sensitive for subtle white-matter lesions³¹ and will also pick up other abnormalities. An

early study of MRI found abnormalities in 77% of the children with CP.³² Most often the finding supported the clinical diagnosis, but in a quarter of cases, it established an unsuspected diagnosis, such as cerebral dysgenesis. Another unexpected finding is PVL in an infant born at term.³³ In this case, it is assumed that the lesion occurred between 24 to 36 weeks gestation, although delivery was after 36 weeks.

Shevell et al¹⁶ reported on subgroups with a particularly high rate of an identifiable etiology. Children with microcephaly or epilepsy were very likely (>90%) to have an etiology determined. Children who had spent time in a neonatal intensive care unit also were very likely to have a definite etiology. Further investigations should include a thrombophilia workup in children with stroke. Children with dysmorphology should have the appropriate genetic investigations. Metabolic investigations may be indicated (eg, a child with dyskinetic CP without a history of encephalopathy may have glutaric aciduria II). Genetic and metabolic investigations should be considered if there is consanguinity or a family history of neurologic disorders. At this point, there is no recommended list of investigations, although as more CP registries are developed, such as the Surveillance of Cerebral Palsy in Europe, it may become possible to define subgroups of children for whom diagnostic investigations are helpful.³⁴

Investigations: Coimpairments

Coimpairments are common in children with CP, often related to the underlying etiology of their CP. The current definition of CP does not take coimpairments into consideration but rather focuses exclusively on the motor impairment. A new definition has been proposed, as a result of the 2004 International Workshop on Definition and Classification of Cerebral Palsy.³⁵ "Cerebral palsy describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behavior, and/or by a seizure disorder."³⁵

All population-based studies of CP find an increased prevalence of these coimpairments. In a Dutch study, 40% of the children had epilepsy, 65% had cognitive deficits (IQ <85), and 34% had visual impairment.³⁶ A study in Scotland and England reported that 23% of their children with CP had an IQ <50, 9% had severe visual loss, and 8% had hearing impairment.³⁷ Shevell et al¹⁶ reported 25% of the children with CP in his pediatric neurology practice had epilepsy.

Child neurologists must assess each child with CP for the presence of coimpairments. The index of suspicion should be high, and, if there are any concerns, the child should have an EEG, audiometry, and/or consultation with an ophthalmologist. Psychological assessment, especially as a child gets close to school age, is imperative if there are any concerns regarding cognitive ability. Because many children with CP have difficulty communicating, the assessment must be performed by a trained neuropsychologist.

After the clinical diagnosis of CP is established and any indicated investigations are completed, the family must be counseled about the diagnosis and its implications for their child and themselves. Parents want to know how “bad” it is and what we and they can do to help their child.³⁸ Often their first question is “Will my child walk?”

Prognosis

The Gross Motor Function Classification System (GMFCS) was developed to follow the natural course of children’s motor development with different “levels” of CP.³⁹ Without a clear understanding of the natural history, it was impossible to critically assess whether a specific intervention actually altered the expected course for that child. Because children with CP, as with all children, develop their motor function over time, it was difficult to determine if an intervention changed the trajectory of their development or if the pre- and postmeasurements simply reflected the expected improvement over time.

The GMFCS describes 5 levels of involvement: level I (least affected) to V (most affected). The motor function at each level

is further divided into 4 age bands: less than 2 years, 2 to 4, 4 to 6, and 6 to 12 years. As an example, Table 2 describes levels I and II. In contrast, children at level V have functional limitations in sitting and standing that cannot be fully compensated for, even with adaptive equipment. At best, children in this level may achieve independent mobility with a power wheelchair with extensive adaptations. The GMFCS can also describe the child’s motor function, especially walking, in different environments.⁴⁰ Walking is not a dichotomous outcome. Children in level III may walk indoors without any assistive devices, may use a walker at school or outside on level surfaces, and use wheeled mobility in the community. Those in level IV may use a walker at home and wheeled mobility elsewhere.

There is some overlap between the GMFCS and the child’s pattern of CP.⁴¹ However, the GMFCS level is superior to either the type of motor impairment or the pattern of limb involvement for prognostication. It is important to point out that the GMFCS does not consider the presence of coimpairments. The presence of a coimpairment, such as visual dysfunction, may affect a child’s motor development.⁴² The GMFCS can be easily used in the busy office because it only requires the age of the child and a description of the child’s basic motor function (head/trunk control, rolling, sitting, walking) to assign a level. Retrospective⁴³ and large prospective trials⁴⁴ have shown the stability of the GMFCS over time. Children at a given level will develop within that level as they get older. The GMFCS can help answer the parents’ questions, “How bad is it?” and “Will my child walk?”

Even after the diagnosis of CP is firmly established, it is important to follow the child and family. Although the child is technically our “patient,” there are significant stresses on the family. Many of these stressors relate directly to the degree of the child’s disability and thus the physical demand on the caregiver, but several are potentially modifiable.

Table 2 GMFCS Levels I and II

GMFCS level I

Before 2nd birthday: move in/out of sitting, floor sit with hands free to manipulate objects, 4-point crawl, pull to stand and cruise furniture, walk independently by 18 to 24 months

From age 2 to 4th birthday: move in/out of sitting and standing, walk as preferred method of mobility

From age 4 to 6th birthday: walk indoors and outdoors, climb stairs, emerging running/jumping

From age 6 to 12th birthday: walk and climb stairs without limitation, able to run and jump but speed, balance and coordination are reduced

GMFCS level II

Before 2nd birthday: floor sit but may use hands for support, commando crawl or 4-point, may pull to stand and cruise

From age 2 to 4th birthday: move in/out of sitting, floor sit with hands free, pull to stand, 4-point crawl, cruise furniture, walk with assistive device as preferred method of mobility

From age 4 to 6th birthday: sit in a chair with hands free to manipulate object, move in/out sitting and standing but may need support, walk short distances indoors and on level ground outdoors without assistive device, climb stair holding rail, not able to run/jump

From age 6 to 12th birthday: walk indoors/outdoors with difficulty on uneven surfaces or in crowds, at best minimal ability to run/jump

Distinctions between levels I and II

Compared with children in level I, children in level II have limitations in the ease of performing movement transitions; walking outdoors and in the community; the need for assistive mobility devices when beginning to walk; quality of movement; and the ability to perform gross motor skills such as running and jumping

Family-Centered Care

Family-centered care has been shown to improve parent satisfaction with the services provided for their child with CP.⁴⁵ Family-centered care includes working with families and providing general information about CP and specific information related to their child, as well as coordinated and comprehensive care provided in a respectful and supportive manner.⁴⁶ By being aware of these issues, we may be able to provide children and families with health care, which helps decrease the stress of having a child with a chronic developmental disability, rather than adding to it.⁴⁷

As well as providing family-centered care, there are other ways to have a positive influence on family function. Caregivers of children with CP, predominantly mothers, experience increased demands compared with mothers of children without disabilities. In a large study of caregivers, 2 of the strongest influences on the caregivers’ psychological and physical health were child behavior and care-giving demands.⁴⁸ The more caregiver assistance a child needed for basic functional activities of daily living, the more likely the caregiver was to have chronic physical or psychological

health concerns. We need to remember to ask families about their support systems and to ensure that caregivers receive adequate respite services. Families need practical help with the day-to-day challenges of caring for a child with CP. We also need to pay attention to concerns about the child's behavior because this is another strong influence on caregiver health. Even if the child's behavior does not reach clinical levels, it may still be a significant stress for the caregiver. We must be sensitive to the presence of these behaviors and react appropriately with parenting strategies, counseling services, or medications, if indicated, to minimize the effect of these behaviors. Family function is the most important mediator of outcome. As physicians, we need interventions that support the entire family. If we recommend interventions for the child, such as night splinting, we need to consider the effect this intervention may have on the family, especially if it affects the child's sleep! In a very real sense, our "patient" is the child with CP and their family. Each time we see the child, we also need to give the family a checkup!

Office Visits

Regular visits are required to ensure that the child is reaching their potential, taking into account the CP as well as any coimpairments. At each visit, it is important to review the child's progress in all aspects of their life (home, school, and community). It is also necessary to review their rehabilitation services to ensure they are receiving the services they require but at the same time are not being overloaded with appointments or home therapy programs. The office visit is a time to discuss support services, such as respite. As previously discussed, child behavior is also particularly important to discuss, in view of the extra stress it may cause parents.

A key part of the visit is reviewing the child's developmental progress. If the child is not progressing as we expected, we need to determine the reason. Although CP, by definition, is not a degenerative condition, there can be complications that impede development (eg, walking may be affected by muscle contractures or pain from dislocated hips). There may be a loss of active range with an increase in spasticity or a loss of passive range, which would indicate contracture. The majority of children with CP have spasticity, but we must consider whether the spasticity is impeding development.

Management of Spasticity

Spasticity is treated to improve function, reduce pain and discomfort, or ease caregiving. We also want to prevent hip subluxation and minimize joint contractures. The severity of spasticity can be assessed by scales, such as the Modified Ashworth Scale,⁴⁹ and the effect of the spasticity can be assessed by measuring the child's active and passive ranges for each major joint. When we assess a child, as well as looking for spasticity and contractures on our formal examination, we need to watch the child move. If the child is unable to walk, we need to determine the most likely reason. Even if they have spasticity, the reason they are unable to walk may relate to poor trunk control, weakness, or severe visual impairment. In those cases, decreasing spasticity will not im-

prove function. However, if the child is able to move about easily in a high-kneel position, then they have adequate postural control for walking, and it is more likely spasticity or contracture, which is interfering with their ability to walk.

There are excellent reviews of spasticity management.^{50,51} Successful management of spasticity requires an organized approach. Initially, we need to assess if there is spasticity and if it is causing a problem by hindering care or function. It is important to assess for underlying weakness because the spasticity may be helpful for function (eg, weight bearing). If the spasticity is believed to be a problem, the next step is to look for aggravating factors, such as pain or poor positioning. Once such factors have been resolved, we need to optimize the physical management of the child, by ensuring appropriate orthoses and stretching regimens. If this does not improve the spasticity, we need to consider other interventions. If the spasticity is focal, local therapy, such as botulinum toxin injections, may be helpful. Oral medications are considered for generalized spasticity. If the spasticity is mainly a problem for lower-limb function or ease of caregiving, selective dorsal rhizotomy or intrathecal baclofen can be considered.

Focal Spasticity

Botulinum toxin was first used for children with CP in 1993.⁵² It was shown to reduce spasticity and improve gait. Since then, there have been many further studies of botulinum toxin in children with CP. Although the toxin does decrease spasticity, not all studies found functional improvement.^{53,54} Other studies have compared botulinum toxin with serial casting for the treatment of equinovarus gait. Again, studies differ in their results. Several studies reported that casting was better than botulinum toxin,⁵⁵ and the combination of botulinum toxin and casting was worse than casting alone, with an earlier recurrence of spasticity and contracture.⁵⁶ Other studies reported that the combination had a longer duration of improved range of motion than casting or botulinum toxin alone.^{57,58} Botulinum toxin is also used for spasticity in the upper limb. The evidence there is equally unclear. Several studies have compared upper-limb botulinum toxin, in combination with occupational therapy to occupational therapy alone. One reported a benefit in function, but not tone, for the combination⁵⁹ and one a benefit in tone but not function.⁶⁰

With such conflicting evidence, it is difficult to know how to proceed. The evidence is reasonably clear that botulinum toxin will reduce spasticity. For many children, the spasticity appears to interfere with their motor development. In those children, a trial of botulinum toxin is reasonable.

Generalized Spasticity

In general, the treatment of spasticity with oral agents is unsatisfactory. The medications often cause drowsiness, which limits dosing. As well, spasticity is reduced throughout the body, which may mean that head and trunk control are affected. The common medications for spasticity are benzodiazepines, baclofen, tizanidine, and dantrolene (Table 3).

Table 3 Medications

Indication	Generic Name	Brand Name	Starting Dose	Maximum Dose
Spasticity	Diazepam	Valium ^a 5-mg tabs	0.05 mg/kg/dose BID-QID ⁷⁸	0.8 mg/kg/d ⁷⁸
	Baclofen	Lioresal ^b 10 20-mg tabs	<2 y 2.5 mg 3 times per day ⁷⁸ 2 to 7 y 5 mg 3 times per day ⁷⁸ >7 y 5 mg 3 times per day ⁷⁸	<2 y 20 mg/d ⁷⁸ 2 to 7 y 40 mg/d ⁷⁸ >7 y 60 mg/d ⁷⁸
	Tizanidine	Zanaflex ^c 4-mg tabs	<10 y 1 mg/d ⁷⁸ >10 y 2 mg/d ⁷⁸	0.3 to 0.5 mg/kg/d ⁷⁸
	Dantrolene	Dantrium ^d 25 100-mg caps	0.5 mg/kg/dose BID ⁷⁸	3 mg/kg/dose to 100 mg QID ⁷⁸
	Modafinil	Alertec ^e 100-mg tabs	3 mg/kg/d ⁶¹	400 mg/d ⁹⁹
	Glycopyrrolate	Robinol Injectable ^f 0.2 mg/mL	Use orally 0.04 mg/kg/dose BID ¹⁰⁰	0.1 mg/kg/dose QID ¹⁰⁰
Drooling	Hydroxyzine	Atarax ^g 2 mg/mL oral 10 25-mg caps	2 mg/kg/d ¹⁰⁰	600 mg/d ¹⁰⁰
	I-dopa/carbidopa	Sinemet 25/100 ^h	0.5 to 2 tabs/d ⁷⁸	2 to 3 tabs/d ⁷⁸
Dystonia	Trihexyphenidyl	Artane ⁱ 2 5-mg tabs	2 mg/d ⁷⁸	60 mg/d ⁷⁸
	Clonazepam	Rivotril ^j 0.5, 2 mg tabs	<30 kg: 0.01 to 0.03 mg/kg/d ¹⁰⁰ >30 kg: 0.5 to 1 mg/d ¹⁰⁰	0.5 to 6 mg/d ⁷⁸
Chorea	Haloperidol	Haldol ^k 2 mg/mL oral 0.5, 1, 2, 5, 10, 20 mg tabs	0.5 mg/d ⁷⁸	0.15 mg/kg/d ⁷⁸ maximum 20 mg/d ⁹⁹
	Levetiracetam	Keppra ^l 250, 500, 750 mg tabs	For epilepsy 10 mg/kg/d*	40 mg/kg/d* 1000 mg BID ⁸⁰

tabs = tablets; QID = 3 times a day; BID = 2 times a day.

*Author's practice.

^aRoche Laboratories (Canada/US) ^bNovartis Pharmaceuticals (Canada) Kemstro manufacturer Schwarz Pharmaceuticals (US) ^cDraxis Health (Canada) Acorda Therapeutics (US) ^dProctor and Gamble Pharmaceuticals (Canada/US) ^eDraxis Health (Canada) Provigil manufacturer Cephalon (US) ^fBaxter Pharmaceutical (US) ^gPfizer (Canada/US) ^hBristol-Myers Squibb (Canada/US) ⁱLederle Laboratories (Canada/US) ^jRoche Laboratories (Canada) Klonopin manufacturer Roche Laboratories (US) ^kOrtho-McNeil Pharmaceutical (Canada/US) ^lUCB Pharmaceutical (Canada/US).

A recent retrospective study using modafinil found that it reduced spasticity in 76% of their sample.⁶¹

Intrathecal baclofen (ITB) allows spasticity to be controlled with low-dose baclofen. The catheter is inserted up to T11 to 12 so it is most helpful for lower-limb spasticity. The infusion rate is programmable and can be set at different rates throughout the day. Initially, ITB was recommended for nonambulatory children to improve ease of caregiving and reduce pain. However, there are reports of children showing improvement in gross motor function after insertion of the pump.^{62,63} There are potential serious complications of ITB. Baclofen lowers the seizure threshold, although in a sample of children with CP and ITB, only 2 of the 60 children with prior epilepsy had an increase in their seizures and 8 actually improved in seizure control.⁶⁴ Of the 90 children without a history of epilepsy, only 1 child developed seizures 4 years after the pump had been inserted. In an accidental overdose, which can happen with a pump malfunction or an error in filling or programming the pump, the child may present with seizures, obtundation, circulatory collapse, and respiratory depression.⁶⁵ Although it is important to recognize the overdose and stop the pump, there is also a severe baclofen withdrawal syndrome. Withdrawal is characterized by fever, hy-

pertension, tachycardia, agitation, and hallucinations. To avoid this syndrome, the patient must be restarted on baclofen, either via the pump (if it is confirmed to be working properly) or by mouth. Withdrawal can also occur with pump malfunctions, catheter breakage, or improper filling. There are concerns of rapid progression of scoliosis after ITB therapy.⁶⁶

Another therapeutic option for spasticity is selective dorsal rhizotomy (SDR). During the procedure, 25% to 60% of the dorsal nerve rootlets from L4-S1 are cut through a L1-S1 laminectomy. The decision of which rootlets to cut is based on the degree of aberrant afferent activity on an intraoperative electromyogram. A meta-analysis of the 3 randomized controlled trials reported a significant decrease in spasticity but a minimal clinical gain in the gross motor function measure (GMFM).⁶⁷ Mittal and coworkers reported a 5 year follow-up after SDR.⁶⁸ Unfortunately, this was not a controlled trial. The authors reported significant clinical and functional gains. Based on these studies, the children who seem to be the best candidates for SDR are ages 3 to 8 years, with spastic diplegia, at GMFCS III and IV. SDR has significant risks. A major concern is worsening of scoliosis, most likely related to the laminectomy.⁶⁹

As well as monitoring the child's spasticity to determine if it is affecting function or caregiving, we need to pay attention to other potential effects of the spasticity, particularly scoliosis and subluxation of the hips. Scoliosis is very common in CP and increases with age and the severity of CP. The risk is highest in those who are nonambulatory.⁷⁰ The curve progresses most quickly during growth spurts but, unlike idiopathic scoliosis, may continue to progress after skeletal maturity. Early detection of the scoliosis is key to slowing progression. External bracing, customized seating inserts, and maintaining good seating posture by correcting any hip and pelvic deformities is important to prevent, or postpone, the need for spinal surgery.

Hip subluxation, and subsequent dislocation, results from spasticity in the hip adductors and iliopsoas muscles. If untreated, this results in acetabular dysplasia and degenerative joint disease. The resulting pain may make prolonged sitting uncomfortable, which has a significant effect on the child's quality of life. As well, the abnormal sitting posture will exacerbate the progression of scoliosis. Routine hip x-rays are important to monitor the degree of hip migration.⁷¹ Stretching and positioning are important to try and prevent subluxation. When these physical maneuvers are insufficient to prevent progression, tendon releases are indicated. Recently, botulinum toxin injections into the hip adductors were found to limit progression of migration.⁷²

Other Office Issues

It is important to monitor the child's growth and nutrition. The North American Growth in Cerebral Palsy research consortium was established to research nutrition and growth issues in this population. They have found that malnutrition is common in children with moderate to severe (GMFCS III-V) CP and is associated with poorer health status, increased utilization of health care resources, and decreased participation in school and community activities.⁷³ Some of the factors that contribute to poor nutrition are amenable to treatment, such as reflux, poor dentition, or constipation, and with attention to these issues, we may be able to make an impact on the child's oral nutrition. When trying to decide if a child is sufficiently malnourished to require a gastrostomy tube, we need to remember that many children with CP will have significant wasting of their leg muscles.⁷⁴ Using typical weight-for-height graphs will give a misleading degree of undernutrition because leg muscles account for up to 25% of an ambulatory child's weight. The North American Growth in Cerebral Palsy consortium is working to develop appropriate measures of growth and nutrition for children with different levels of CP.

Drooling is another area in which we can make a difference. Children with CP, as a result of impaired swallowing and poor lip closure, often drool considerably. This has social consequences and also results in damage to computers and communication devices.⁷⁵ Anticholinergic medications are the mainstay of treatment but have significant side effects⁷⁶ (Table 3). Recently, botulinum toxin injections into the pa-

rotid glands were reported to decrease salivary flow without significant side effects.⁷⁷

Involuntary movements may interfere with function and be reduced with medication (Table 3). The response is often not complete but may be helpful. For dystonia, levodopa is the initial medication.⁷⁸ There is a report that children may respond better to trihexyphenidyl.⁷⁹ Chorea may respond to benzodiazepines, such as clonazepam, or dopamine-depleting medications, such as haloperidol. A recent case study in an adult reported success with levetiracetam.⁸⁰

Children with hemiparetic CP have an abnormal gait and usually a marked decrease in bimanual dexterity. There are several new therapeutic regimes for children with hemis syndromes. Balance training, using a programmable moving platform, has been shown to improve the symmetry of gait.⁸¹ Constraint-induced movement therapy, which involves restraining the unaffected arm and hand for prolonged periods (often several weeks with a cast), is generally well tolerated by the children and results in increased use of the affected hand.⁸²

Alternative and Complementary Therapies

It is important to be aware of current alternative and complementary therapies, especially those in your region. Families have a right to expect that we will be honest and forthright regarding all possible treatment options, and they should feel comfortable discussing this with us.⁸³ We must share any scientific information on these options. Rosenbaum⁸⁴ has an excellent review of alternative therapy. A recent PubMed search using the MeSH terms "alternative OR complementary therapy AND cerebral palsy" revealed 299 citations. When the search was limited to humans, 0 to 18 years, and randomized controlled trial, the list was reduced to 11 articles over 25 years. In contrast, a Google search, using the same terms, gave 1,640,000 hits. Even with these limits, there are 128,000 sites. It would be impossible for a family to navigate their way through all this. We have a responsibility to explain to families any evidence that is available about these treatments, just as we do for the interventions we recommend. Even therapies, which on first glance do not seem harmful to the child, require the family to divert time and energy and often significant amounts of money away from activities that may be more beneficial.

Conductive Education

Conductive education is a program imported from Hungary. In its original form, it was very intensive and time consuming for the child and the family. The children lived in the "institute" and a "conductor" acted as "mother, teacher, and physio-occupational and speech therapist."⁸⁵ The children had 13-hour days, devoted to "rhythmical intention," where, by singing and counting aloud, they learned a motor task. Living at the institute and spending all of their time on refining motor tasks, impacted on the child's family life, social development, and academic achievement. Many families use modifications of the original method, such as joining together to sponsor a "conductor" from Hungary several weeks a year for intensive

sessions. A recent study compared a single intensive period of conductive education to ongoing sessions and found that the single session was as effective in facilitating small motor-function gains and that ongoing sessions were of limited value.⁸⁶ Other families are requesting that conductive education become a part of their child's schooling.⁸⁷ The American Academy of Cerebral Palsy and Developmental Medicine published an evidence report regarding conductive education.⁸⁸ The Treatment Outcomes Committee Review Panel reviewed all published literature on conductive education. At present, there is no evidence to support a benefit.

Hyperbaric Oxygen

In the 1990s, Neubauer and James⁸⁹ proposed hyperbaric oxygen as a cure for cerebral palsy and stroke. As with any medically incurable condition, when a promise of a "cure" is made, there was a great deal of interest and many testimonials by families. An initial open-label study from Montreal, Canada, reported significant gains in motor function.⁹⁰ Although the gains in motor function, measured objectively by the GMFM, were real, the magnitude was typical of what would have been expected with physiotherapy alone. In 2001, the same research group performed a well-designed, multicenter, randomized, placebo-controlled study. None of the objective motor⁹¹ or neuropsychological⁹² measures showed a difference between groups, and, importantly, both parent groups reported the same level of change.

Transition

As the child transitions through different developmental stages, it is important to address new issues that arise. These issues may include behaviors, such as the "terrible twos" or exposure to new environments. Families may need help and support finding an appropriate day care or dealing with the child's school. There may be questions regarding recreational activities, such as therapeutic horseback riding or wheelchair dance or questions about vocational options for the adolescent and young adult. It is important that we modify our interactions with the child and parents as the child matures. As physicians for children, we are comfortable talking with parents and may forget to address questions to the older child or adolescent. This is a particular risk when we have known the child and family for many years because we have established a communication pattern that may be hard for us, and the parents, to change.

CP is often considered as only a pediatric condition. In the past, many children with CP, particularly those with spastic quadriplegic CP, did not survive to adulthood.⁹³ A recent study looked at a British birth cohort from 1940 to 1950.⁹⁴ For those with CP alive at age 20 years, 85% survived until age 50 years. Although this is lower than the 96% in the general population, it does emphasize the need to plan for the transition of "our" children to adult CP clinics. Adults with CP have ongoing health issues, above and beyond all the typical health concerns of the general aging population.⁹⁵ Many adults will have deterioration in walking ability, perhaps because of weakness, fatigue, pain, or orthopedic com-

plications, such as scoliosis or dislocated hips. Clearly ongoing surveillance for these complications, during childhood, is important to their future. In addition, their integration into society, including the workforce, is related to their integration as children.⁹⁶ Both the Canadian Pediatric Society⁹⁷ and the American Academy of Pediatrics⁹⁸ have recently issued policy statements on improving care and transition for adolescents with chronic health care conditions.

Conclusion

Pediatric neurologists have a huge impact on the lives of children with CP and their families. This impact continues well into the future for many of the children we follow in our practices. The care we provide must extend past the initial diagnosis.

References

1. Mutch L, Alberman E, Hagberg B, et al: Cerebral palsy epidemiology: Where are we now and where are we going? *Dev Med Child Neurol* 34:547-551, 1992
2. Gupta R, Appleton RE: Cerebral palsy: Not always what it seems. *Arch Dis Child* 85:356-360, 2001
3. Nelson KB, Ellenberg JH: Children who "outgrew" cerebral palsy. *Pediatrics* 69:529-536, 1982
4. Kuban KCK, Leviton A: Cerebral palsy. *N Engl J Med* 330:188-195, 1994
5. Keogh JM, Badawi N: The origins of cerebral palsy. *Curr Opin Neurol* 19:129-134, 2006
6. Ancel P-Y, Livinec F, Larroque B, et al: Cerebral palsy among very preterm children in relation to gestation age and neonatal ultrasound abnormalities: the EPIPAGE cohort study. *Pediatrics* 117:828-835, 2006
7. O'Shea TM, Counsell SJ, Bartels DB, et al: Magnetic resonance and ultrasound brain imaging in preterm infants. *Early Hum Dev* 81:263-271, 2005
8. Mirmiran M, Barnes PD, Keller K, et al: Neonatal brain magnetic resonance imaging before discharge is better than serial cranial ultrasound in predicting cerebral palsy in very low birth weight preterm infants. *Pediatrics* 114:992-998, 2004
9. Maruyama K, Okumura A, Hayakawa F, et al: Prognostic value of EEG depression in preterm infants for later development of cerebral palsy. *Neuropediatrics* 33:133-137, 2002
10. Hoyert DL, Mathews TJ, Menacker F, et al: Annual summary of vital statistics:2004. *Pediatrics* 117:168-183, 2006
11. Wilson-Costello D, Friedman H, Minich N, et al: Improved survival rates with increased neurodevelopmental disability for extremely low birth weight infants in the 1990s. *Pediatrics* 115:997-1003, 2005
12. Marlow N, Wolke D, Bracewell MA, et al, for the EPICure Study Group: Neurologic and developmental disability at six years of age after extremely preterm birth. *N Engl J Med* 352:9-19, 2005
13. Shevell MI: The "Bermuda triangle" of neonatal neurology: Cerebral palsy, neonatal encephalopathy and intrapartum asphyxia. *Semin Pediatr Neurol* 11:24-30, 2004
14. Sarnat HB, Sarnat MS: Neonatal encephalopathy following fetal distress. A clinical and electroencephalographic study. *Arch Neurol* 33:696-705, 1976
15. Ellenberg JH, Nelson KB: Cluster of perinatal events identifying infants at high risk for death or disability. *J Pediatr* 113:546-552, 1988
16. Shevell MI, Majnemer A, Morin I: Etiologic yield of cerebral palsy: A contemporary case series. *Pediatr Neurol* 28:352-359, 2003
17. Badawi N, Felix JF, Kurinczuk JJ, et al: Cerebral palsy following term newborn encephalopathy. *Dev Med Child Neurol* 47:293-298, 2005
18. Selton D, Andre M: Prognosis of hypoxic-ischemic encephalopathy in full-

- term newborns—Value of neonatal encephalography. *Neuropediatrics* 28:276-280, 1997
19. van Rooij LGM, Toet MC, Osredkar D, et al: Recovery of amplitude integrated electroencephalographic background patterns within 24 hours of perinatal asphyxia. *Arch Dis Child Fetal Neonatal Ed* 90: F245-F251, 2005
 20. Barkovich AJ, Westmark K, Partridge C, et al: Perinatal asphyxia: MR findings in the first 10 days. *AJNR Am J Neuroradiol* 16:427-438, 1995
 21. Barkovich AJ, Baranski K, Vigneron D, et al: Proton MR spectroscopy for the evaluation of brain injury in asphyxiated, term neonates. *AJNR Am J Neuroradiol* 20:1399-1405, 1999
 22. L'Abée C, de Vries LS, van der Grond J: Early diffusion-weighted MRI and H-magnetic resonance spectroscopy in asphyxiated full-term neonates. *Biol Neonate* 88:306-312, 2005
 23. Nelson KB, Lynch JK: Stroke in newborn infants. *Lancet Neurol* 3:150-158, 2004
 24. Sreenan C, Bhargava R, Robertson CM: Cerebral infarction in the term newborn: Clinical presentation and long-term outcome. *J Pediatr* 137: 351-355, 2000
 25. Wu YW, March WM, Croen LA, et al: Perinatal stroke in children with motor impairment: A population-based study. *J Pediatr* 114:612-619, 2004
 26. Lee J, Croen LA, Backstrand KH, et al: Maternal and infant characteristics associated with perinatal arterial stroke in the infant. *JAMA* 293:723-729, 2005
 27. Nelson KB, Dambrosia JM, Grether JK, et al: Neonatal cytokines and coagulation factors in children with cerebral palsy. *Ann Neurol* 44: 665-675, 1998
 28. Mercuri E, Cowan F, Gupta G, et al: Prothrombotic disorders and abnormal neurodevelopmental outcome in infants with neonatal cerebral infarction. *Pediatrics* 107:1400-1404, 2001
 29. Reid S, Halliday J, Ditchfield M, et al: Factor V Leiden mutation: a contributory factor for cerebral palsy. *Dev Med Child Neurol* 48:14-19, 2006
 30. Cans C, McManus V, Crowley M, et al: Cerebral palsy of post-neonatal origin: Characteristics and risk factors. *Paediatr Perinat Epidemiol* 18:214-220, 2004
 31. Rademaker KJ, Uiterwaal CSPM, Beek FJA, et al: Neonatal cranial ultrasound versus MRI and neurodevelopmental outcome at school age in children born preterm. *Arch Dis Child Fetal Neonatal Ed* 90: F489-F493, 2005
 32. Candy EJ, Hoon AH, Capute AJ, et al: MRI in motor delay: Important adjunct to classification of cerebral palsy. *Pediatr Neurol* 9:421-429, 1993
 33. Serdaroglu G, Tekgul H, Kitis O, et al: Correlative value of magnetic resonance imaging for neurodevelopmental outcome in periventricular leukomalacia. *Dev Med Child Neurol* 46:733-739, 2004
 34. Cans C, Surman G, McManus V, et al: Cerebral palsy registries. *Semin Pediatr Neurol* 11:18-23, 2004
 35. Executive Committee for the Definition of Cerebral Palsy, Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N: Proposed definition and classification of cerebral palsy, April 2005. *Dev Med Child Neurol* 47:571-576, 2005
 36. Wichers MJ, Odding E, Stam HJ, et al: Clinical presentation, associated disorders and aetiological moments in cerebral palsy: A Dutch population-based study. *Disabil Rehabil* 27:583-589, 2005
 37. Pharoah POD, Cooke T, Johnson MA, et al: Epidemiology of cerebral palsy in England and Scotland, 1984-9. *Arch Dis Child Fetal Neonatal Ed* 79:F21-F25, 1998
 38. Rosenbaum P: Cerebral palsy: What parents and doctors want to know. *BMJ* 326:970-974, 2003
 39. Palisano R, Rosenbaum P, Walter S, et al: Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 39:214-223, 1997
 40. Palisano RJ, Tieman BL, Walter SD, et al: Effect of environmental setting on mobility methods of children with cerebral palsy. *Dev Med Child Neurol* 45:113-120, 2003
 41. Gorter JW, Rosenbaum PL, Hanna SE, et al: Limb distribution, motor impairment, and functional classification of cerebral palsy. *Dev Med Child Neurol* 46:461-467, 2004
 42. Porro G, van der Linden D, van Nieuwenhuizen O, et al: Role of visual dysfunction in postural control in children with cerebral palsy. *Neural Plast* 12:205-210, 2005
 43. Wood E, Rosenbaum P: The Gross Motor Function Classification System for cerebral palsy: A study of reliability and stability over time. *Dev Med Child Neurol* 42:292-296, 2000
 44. Rosenbaum PL, Walter SD, Hanna SE, et al: Prognosis for gross motor function in cerebral palsy. *JAMA* 288:1357-1363, 2002
 45. Law M, Hanna S, King G, et al: Factors affecting family-centered service delivery for children with disabilities. *Child Care Health Dev* 29:357-366, 2003
 46. King GA, Rosenbaum PL, King SM: Evaluating family-centered service using a measure of parents' perceptions. *Child Care Health Dev* 23: 47-62, 1997
 47. King S, Teplicky R, King G, et al: Family-centered service for children with cerebral palsy and their families: A review of the literature. *Semin Pediatr Neurol* 11:78-86, 2004
 48. Raina P, O'Donnell M, Rosenbaum P, et al: The health and well-being of caregivers of children with cerebral palsy. *Pediatrics* 115:626-636, 2005
 49. Clopton N, Dutton J, Featherston T, et al: Interrater and intrarater reliability of the Modified Ashworth Scale in children with hypertonia. *Pediatr Phys Ther* 17:268-274, 2005
 50. Thompson AJ, Jarrett L, Lockley L, et al: Clinical management of spasticity. *J Neurol Neurosurg Psychiatry* 76:459-463, 2005
 51. Tilton AH: Therapeutic interventions for tone abnormalities in cerebral palsy. *NeuroRx* 3:217-224, 2006
 52. Koman LA, Mooney JF, Smith B, et al: Management of cerebral palsy with botulinum-A toxin: Preliminary investigation. *J Pediatr Orthop* 13:489-495, 1993
 53. Baker R, Jasinski M, Maciag-Tymiecka I, et al: Botulinum toxin treatment of spasticity in diplegic cerebral palsy: A randomized, double-blind, placebo-controlled dose-ranging study. *Dev Med Child Neurol* 44:666-675, 2002
 54. Reddihough DS, King JA, Coleman GJ, et al: Functional outcome of botulinum toxin A injections to the lower limbs in cerebral palsy. *Dev Med Child Neurol* 44:820-827, 2002
 55. Glanzman AM, Kim H, Swaminathan K, et al: Efficacy of botulinum toxin A, serial casting, and combined treatment for spastic equines: A retrospective analysis. *Dev Med Child Neurol* 46:807-811, 2004
 56. Kay RM, Rethlefsen SA, Fern-Bunéo A, et al: Botulinum toxin as an adjunct to serial casting treatment in children with cerebral palsy. *J Bone Joint Surg Am* 86A:2377-2384, 2004
 57. Ackman JD, Russman BS, Thomas SS, et al: Comparing botulinum toxin A with casting for treatment of dynamic equines in children with cerebral palsy. *Dev Med Child Neurol* 47:620-627, 2005
 58. Bottos M, Benedetti MG, Salucci P, et al: Botulinum toxin with and without casting in ambulant children with spastic diplegia: A clinical and functional assessment. *Dev Med Child Neurol* 45:758-762, 2003
 59. Fehlings D, Rang M, Glazier J, et al: An evaluation of botulinum-A toxin injections to improve upper extremity function in children with hemiplegic cerebral palsy. *J Pediatr* 137:300-303, 2000
 60. Speth LA, Leffers P, Janssen-Potten YJ, et al: Botulinum toxin A and upper limb functional skills in hemiparetic cerebral palsy: A randomized trial in children receiving intensive therapy. *Dev Med Child Neurol* 47:468-473, 2005
 61. Hurst DL, Lajara-Nanson WA, Lance-Fish ME: Walking with modafinil and its use in diplegic cerebral palsy: retrospective review. *J Child Neurol* 21:294-297, 2006
 62. Krach LE, Kriel RL, Gilmartin RC, et al: GMFM 1 year after continuous intrathecal baclofen infusion. *Pediatr Rehabil* 8:207-213, 2005
 63. Gerszten PC, Albright AL, Barry MJ: Effect on ambulation of continuous intrathecal baclofen infusion. *Pediatr Neurosurg* 27:40-44, 1997
 64. Buonaguro V, Scelsa B, Curci D, et al: Epilepsy and intrathecal baclofen therapy in children with cerebral palsy. *Pediatr Neurol* 33:110-113, 2005
 65. Darbari FP, Melvin JJ, Piatt JH, et al: Intrathecal baclofen overdose

- followed by withdrawal: Clinical and EEG features. *Pediatr Neurol* 33:373-377, 2005
66. Sansone JM, Mann D, Noonan K, et al: Rapid progression of scoliosis following insertion of intrathecal baclofen pump. *J Pediatr Orthop* 26:125-128, 2006
 67. McLaughlin J, Bjornson K, Temkin N, et al: Selective dorsal rhizotomy: Meta-analysis of three randomized controlled trials. *Dev Med Child Neurol* 44:17-25, 2002
 68. Mittal S, Farmer JP, Al-Atassi B, et al: Functional performance following selective posterior rhizotomy: Long-term results determined using a validated evaluative measure. *J Neurosurg* 97:510-518, 2002
 69. Steinbok P, Hicdonmez T, Sawatzky B, et al: Spinal deformities after selective dorsal rhizotomy of spastic cerebral palsy. *J Neurosurg* 102: S363-S373, 2005
 70. Morrell DS, Pearson JM, Sauser DD: Progressive bone and joint abnormalities of the spine and lower extremities in cerebral palsy. *Radiographics* 22:257-268, 2002
 71. Spiegel DA, Flynn JM: Evaluation and treatment of hip dysplasia in cerebral palsy. *Orthop Clin North Am* 37:185-196, 2006
 72. Pidcock FS, Fish DE, Johnson-Greene D, et al: Hip migration percentage in children with cerebral palsy treated with botulium toxin type A. *Arch Phys Med Rehabil* 86:431-435, 2005
 73. Samson-Fang L, Fung E, Stallings VA, et al, the North American Growth in Cerebral Palsy Project: Relationship of nutritional status to health and societal participation in children with cerebral palsy. *J Pediatr* 141:637-643, 2002
 74. Kong C-K, Wong H-S S: Weight-for-height values and limb anthropometric composition of tube-fed children with quadriplegic cerebral palsy. *Pediatrics* 116:839-845, 2005
 75. Van der Burg JJ, Jongerius PH, Van Hulst K, et al: Drooling in children with cerebral palsy: Effect of salivary flow reduction on daily life and care. *Dev Med Child Neurol* 48:103-107, 2006
 76. Bachrach SJ, Walter RS, Trzcinski K: Use of glycopyrrolate and other anticholinergic medications for sialorrhea in children with cerebral palsy. *Clin Pediatr* 37:485-490, 1998
 77. Bothwell JE, Clarke K, Dooley JM, et al: Botulium toxin A as a treatment for excessive drooling in children. *Pediatr Neurol* 27:18-22, 2002
 78. Edgar TS: Oral pharmacotherapy of childhood movement disorders. *J Child Neurol* 18:S40-S49, 2003
 79. Hoon AH, Freese PO, Reinhardt EM, et al: Age-dependent effects of trihexyphenidyl in extrapyramidal cerebral palsy. *Pediatr Neurol* 25: 55-58, 2001
 80. Recio MV, Hauser RA, Louis ED, et al: Chorea in a patient with cerebral palsy: Treatment with levetiracetam. *Mov Disord* 20:762-764, 2005
 81. Ledebt A, Becher J, Kapper J, et al: Balance training with visual feedback in children with hemiplegic cerebral palsy: Effect on stance and gait. *Motor Control* 9:459-968, 2005
 82. Sung I-Y, Ryu J-S, Pyun S-B, et al: Efficacy of forced-use therapy in hemiplegic cerebral palsy. *Arch Phys Med Rehabil* 86:2195-2198, 2005
 83. Liptak GS: Complementary and alternative therapies for cerebral palsy. *Ment Retard Dev Disabil Res Rev* 11:156-163, 2005
 84. Rosenbaum P: Controversial treatment of spasticity: Exploring alternative therapies for motor function in children with cerebral palsy. *J Child Neurol* 18:S89-S94, 2003
 85. Cotton E: The Institute for Movement Therapy and School for "Conductors," Budapest, Hungary. *Dev Med Child Neurol* 7:437-446, 1965
 86. Odman P, Oberg B: Effectiveness of intensive training for children with cerebral palsy—A comparison between child and youth rehabilitation and conductive education. *J Rehabil Med* 37:263-270, 2005
 87. Wright FV, Boschen K, Jutai J: Exploring the comparative responsiveness of a core set of outcome measures in a school-based conductive education programme. *Child Care Health Dev* 31:291-302, 2005
 88. Darrah J, Watkins B, Chen L, et al: Conductive education intervention for children with cerebral palsy: An AACPD evidence report. *Dev Med Child Neurol* 46:187-203, 2004
 89. Neubauer RA, James PB: Cerebral oxygenation and the recoverable brain. *Neurol Res* 20:S33-S36, 1998
 90. Montgomery D, Goldberg J, Amar M, et al: Effects of hyperbaric oxygen therapy on children with spastic diplegic cerebral palsy: A pilot project. *Undersea Hyperb Med* 26:235-242, 1999
 91. Collet JP, Vanasse M, Marois P, et al: Hyperbaric oxygen therapy for children with cerebral palsy: A multicenter placebo controlled randomized clinical trial. *Lancet* 357:582-586, 2001
 92. Hardy P, Collet JP, Goldberg J, et al: Neuropsychological effects of hyperbaric oxygen therapy in cerebral palsy. *Dev Med Child Neurol* 44:436-446, 2002
 93. Strauss D, Shavelle R: Life expectancy of adults with cerebral palsy. *Dev Med Child Neurol* 40:369-375, 1998
 94. Hemming K, Hutton JL, Pharoah POD: Long-term survival for a cohort of adults with cerebral palsy. *Dev Med Child Neurol* 48:90-95, 2006
 95. Bottos M, Felicangeli A, Sciuto L, et al: Functional status of adults with cerebral palsy and implications for treatment of children. *Dev Med Child Neurol* 43:516-528, 2110
 96. Michelsen SI, Uldall P, Kejs AMT, et al: Education and employment prospects in cerebral palsy. *Dev Med Child Neurol* 47:511-517, 2005
 97. Canadian Pediatric Society Adolescent Health Committee: Care of adolescents with chronic health conditions. *Paediatr Child Health* 11:43-48, 2006
 98. American Academy of Pediatrics: Improving transition for adolescents with special health care needs from pediatric to adult-centered health care. *Pediatrics* 110:1301-1335, 2002 (suppl 2)
 99. Compendium of Pharmaceuticals and Specialties: The Canadian Drug Reference for Health Professionals. Canadian Pharmacists Association. Webcom Limited. Ottawa, ON, Canada, 2006
 100. Formulary of Drugs and Dosing Manual 2004/2005. IWK Health Centre, Halifax, NS, Canada