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# Cerebral Palsy: an Analysis of Hip Pathology and Possible Treatments

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## **Introduction**

Cerebral Palsy (CP) occurs in about one to five of every 1000 births in Western countries (DeLuca 1996), and is also the most common cause of severe physical disability in childhood (Koman et al. 2004). Cerebral Palsy is an umbrella term used to describe a number of conditions that are caused by brain damage during fetal development or shortly after birth, and that are characterized by poor muscle control, spasticity (muscle tightness), and paralysis, among many other neurological deficiencies (Berkow 1997). The magnitude of these manifestations depends on the extent and location of the brain damage and can range in severity from subtle motor impairment to total body involvement (Koman et al. 2004).

Cerebral Palsy is a static, rather than progressive disorder, where the condition will not worsen over time (DeLuca 1996). Brain damage usually occurs in the cerebral cortex, which can result in many Central Nervous System (CNS) impairments such as: CNS hemorrhage (ruptured blood vessel in the central nervous system), mechanical spinal cord or brainstem damage, deep CNS hypoxia (deprivation of oxygen), cerebral cortex hypoxia and transient or irreversible ischemia (blood deficiency to the brain, which results in nervous/brain cell death). Cerebral Palsy is usually diagnosed based on delayed development of motor function (Eicher and Batshaw 1995). The causes of Cerebral Palsy, as well as the symptoms, diagnosis, classification, associated medical problems and the prognosis will be discussed in the next chapter.

## **Chapter I: What is Cerebral Palsy?**

### Causes of Cerebral Palsy:

Many factors influence the presence of CP, and many causes have been identified, although the exact cause remains unknown. The most common of these causes is a combination of pre-maturity and low birth weight (DeLuca 1996). It has been found that infants having birth weight of less than 1.5 kg have an increased chance for Cerebral Palsy than infants born weighting more than 2.5 kg (DeLuca 1996). However, many other factors may cause Cerebral Palsy, including brain injury and poor oxygen supply to the brain before, during and immediately following birth which causes brain injury, (Berkow 1997). Furthermore, CP may be caused by illness after birth, such as; meningitis, sepsis, or trauma (Berkow 1997).

### Symptoms:

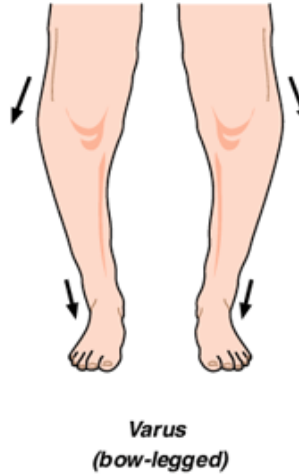
Symptoms of Cerebral Palsy are varied and range in severity and while most of the symptoms are physical, cognitive and sensory deficits may also be present. General physical symptoms of Cerebral Palsy include: joint contractures which are due to permanent spasticity or muscle tightening, physical growth delay, and persistent primitive reflexes including the Moro reflex, asymmetric tonic neck reflex, and palmer grasp all of which are described below (Thorogood et al. 2005). The continued presence of these reflexes into early childhood (after about one year), as well as joint contractures, and

delay of physical growth are all physical symptoms of Cerebral Palsy, but the most obvious physical symptoms of Cerebral Palsy are related to gait, or walking patterns.

During the first four to nine months, babies typically lose their newborn reflexes. However, in the CP baby these reflexes persist. The Moro reflex is stimulated by dropping the head backwards and results in an extension and bringing together of the hands. It may also result in the splaying of fingers. This reflex develops by 41 weeks, but is inactive at five months in a typical infant. The asymmetric tonic neck reflex is stimulated by flexing or extending the infant's head, and the result is an opposite movement of the head, arms and hips. With the head in flexion, the arms will flex and the hips will extend, while when the head is in extension, the arms will extend and the hips will flex. Finally, the palmar grasp is a result of pressure on the palm of an infant's hand. When pressure is exerted on the hand, the infant will flex the fingers in order to hold the object applying pressure (Eigsti 2006).

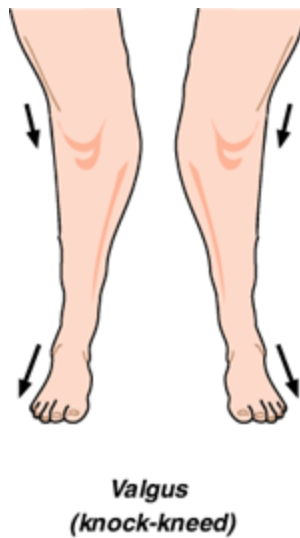
Abnormal walking patterns or the inability to walk at all is often seen in Cerebral Palsy and is caused by lower extremity impairments (Thorogood et al. 2005). At the hip, excessive flexion, adduction and femoral anteversion are observed, while flexion and extension are hindered in the knee by varus (Figure 1) or valgus stress presentation (Figure 2). In the foot, toe walking and varus or valgus positions of the hind foot are most common (Thorogood et al. 2005). All of these joint factors contribute to a pathological gait, such as crouch gait, weak quadriceps and/or excessive dorsiflexion of the foot (flexed foot with the toes flexed toward the body) with varus and valgus presentation, as well as many other abnormalities (Thorogood et al. 2005).

Figure 1: Varus Presentation



(Comparison of Varus and Valgus Deformity . Retrieved April 19, 2007, from Merck Medicus Web site:  
<http://www.merckmedicus.com/ppdocs/us/hcp/diseasemodules/osteoarthritis/figures/figure19.html>)

Figure 2: Valgus Presentation



(Comparison of Varus and Valgus Deformity . Retrieved April 19, 2007, from Merck Medicus Web site:  
<http://www.merckmedicus.com/ppdocs/us/hcp/diseasemodules/osteoarthritis/figures/figure19.html>)



Other non-physical symptoms of Cerebral Palsy include cognitive and sensory deficits such as: mental retardation, sensory-motor and coordination deficits, behavior abnormalities, disturbances in perception, and fine motor abilities as well as decreased ability to react to stimuli. Children with Cerebral Palsy may also experience learning problems, and auditory and visual deficits. Finally, children with Cerebral Palsy tend to experience seizures and epilepsy (Vining et al. 1976).

#### Diagnosis:

Diagnosis of Cerebral Palsy usually occurs before age five, as this is the time when most motor development has already occurred. Most children with Cerebral Palsy can be diagnosed before 18 months, and many tests can be performed to confirm the diagnosis (Miller and Barach 1995). Cerebral Palsy may be suspected when motor milestones are missed. For example, a child normally reaches for toys at three to four months, sits at six to seven months and begins to walk by 14 months (Miller and Barach 1995), and if a child is slow to develop these skills then Cerebral Palsy may be suspected. When making the diagnosis, the physician will focus not only on the delay of motor skills, but also on other physical warning signs including abnormal muscle tone, abnormal movements and persistent infantile reflexes, as mentioned above (Miller and Barach 1995). Also, infants with Cerebral Palsy can either be “floppy” or incredibly stiff, which can contribute to the process of diagnosis (Figure 3).

Figure 3: Floppy Presentation of Cerebral Palsy in Infants



("Cerebral Palsy." Disabled Village Children. 1987. Disabled Village Children . 26 Feb 2007)

Laboratory tests may also contribute to the diagnosis. Magnetic Resonance Imaging (MRI) and Computerized Tomography (CT) scans may be used to analyze the structure of the brain and possibly identify a brain injury that could indicate Cerebral Palsy (Miller and Barach 1995). Other laboratory tests, such as chromosome, thyroid outcome, lactate level outcome, pyruvate level analysis, organic and amino acid analysis, and cerebrospinal protein analysis (Thorogood et. al 2005) may help eliminate other possible diagnoses and eventually lead to a diagnosis of Cerebral Palsy. It is important to remember that CP can be very difficult to diagnose due to the broad range of symptoms. As a result, many tests may be needed to come to a final diagnosis. Once CP is diagnosed, it can be classified further into types based on the location and type of movement expressed.

#### Classification:

CP is classified based on physical characteristics presented, as well as the location of the abnormality. The four classifications of Cerebral Palsy are: Spastic, Ataxic,

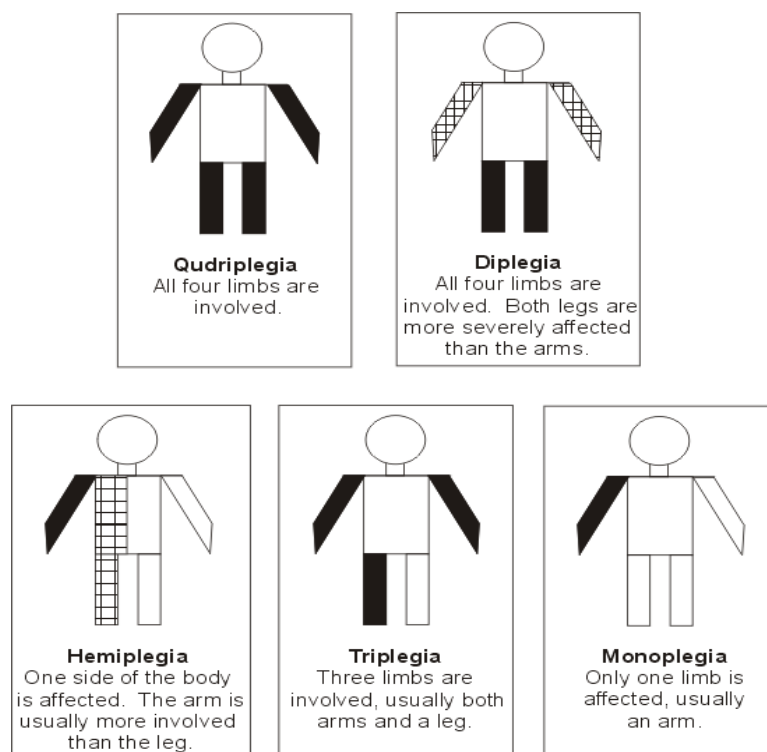
Athetoid and Mixed (Table 1). Spastic Cerebral Palsy is characterized by stiff and jerky movements as a result of high muscle tone (National Institute of Neurological Disorders and Stroke (NINDS) 2006)). The patient with this type of Cerebral Palsy may have trouble walking, gripping or manipulating objects, depending on the scope of areas affected. Ataxic Cerebral Palsy is essentially the opposite of Spastic Cerebral Palsy. Patients with the Ataxic type have low muscle tone and poor coordination of movements. They may also have difficulty walking and walk with legs spread far apart. The third type of Cerebral Palsy is Athetoid Cerebral Palsy, which is also called Dyskinetic Cerebral Palsy, and involves uncontrolled jerks or slow, withering movements in the hands, feet, arms, legs, face and upper extremity, as well as hyperactivity in the muscles of the face and tongue, which can cause drooling. Overall, intelligence is rarely affected in this type of Cerebral Palsy. Finally, Mixed Cerebral Palsy is a combination of one or more types and usually involves combination of athetoid and spastic Cerebral Palsy. Patients with all types may also experience an increase of symptom severity with stress. Thus, it is extremely important to evaluate and manage stress levels for all patients with Cerebral Palsy (Handbook of Disabilities 2006).

Table 1: Types of Cerebral Palsy

<b>Type</b>	<b>Description</b>
Spastic	Rigid
Ataxic	Difficulty coordinating voluntary movements
Athetoid	No muscle control
Mixed	All symptoms present

Aside from classification based on the type of movements observed, Cerebral Palsy is also described based on the location of the abnormality. One or more limbs may be involved and may be weakened or completely paralyzed. Latin terms describe the number of limbs involved; hemi indicates one side (half), and quad indicates that all four limbs are involved. The terms paresis (weakened) and plegia (completely paralyzed) are then added to describe the type of disability (NINDS 2006). For example, hemiplegia involves paralysis of one arm and one leg on the same side, while diplegia indicates paralysis in both legs predominantly, although arms are usually involved. Paralysis rarely occurs in the upper extremity alone. Quadriplegia refers to the paralysis of all four extremities (Miller and Bachrach 1995). Monoplegia involves paralysis of only one limb, while triplegia describes paralysis of three limbs. These same terms can be used to describe weakness in the same patterns by adding the ending “paresis” to the same suffix (Figure 4).

**Figure 4: Limb involvement in Cerebral Palsy**



("What is Cerebral Palsy ." [Ontario Federation for Cerebral Palsy](http://www.ofcp.on.ca/aboutcp.html##T). 26 Feb 2007. Ontario Federation for Cerebral Palsy . 26 Feb 2007 <http://www.ofcp.on.ca/aboutcp.html##T>).

### Prognosis:

The prognosis of Cerebral Palsy is highly dependent on the type of CP. For patients with Spastic quadriplegia, about 23% have little to no functional limitations in ambulation or self-care, while 50% will have moderate impairment, and nearly 25% will be severely impaired, are not ambulatory and will require complete care (Thorogood et al. 2005). For patients with Athetoid Cerebral Palsy, 50% are ambulatory. Overall, the prognosis of Cerebral Palsy depends on the individual, the number of limbs involved, the

severity of presentation, the medical conditions associated with Cerebral Palsy and the interventions and resources available to patients and their families.

#### Medical Conditions Associated with Cerebral Palsy:

Even though Cerebral Palsy mainly involves movement disorders, many other symptoms are associated with Cerebral Palsy. These symptoms include, but are not limited to, seizures, visual impairment, hearing impairment, mental retardation, irregular breathing, feeding and swallowing problems, drooling, skin irritation (associated with drooling), incontinence caused by poor bladder control, contractures which can cause shortening of affected limbs, a slower rate of development and reduced proprioception (awareness of the location of limbs in space) (NINDS 2006). Attention deficit-hyperactivity disorder, hydrocephalus (water on the brain), behavior problems, and swallowing difficulties are also observed in patients with Cerebral Palsy (Miller and Barach 1995). Furthermore, secondary effects of Cerebral Palsy include: poor growth, poor nutrition, aspiration pneumonia as a result of swallowing deficiencies, gastroesophageal reflux, frequent fractures due to lower bone density, constipation, sleep disorders, upper airway obstruction, communication disorder, hernia and bladder control problems (Miller and Barach 1995). A wide variety of pathologies are associated with Cerebral Palsy, but it is important to remember that not all symptoms occur in every individual.

## **Chapter II: Basic Description of Brain Anatomy and Cerebral Palsy**

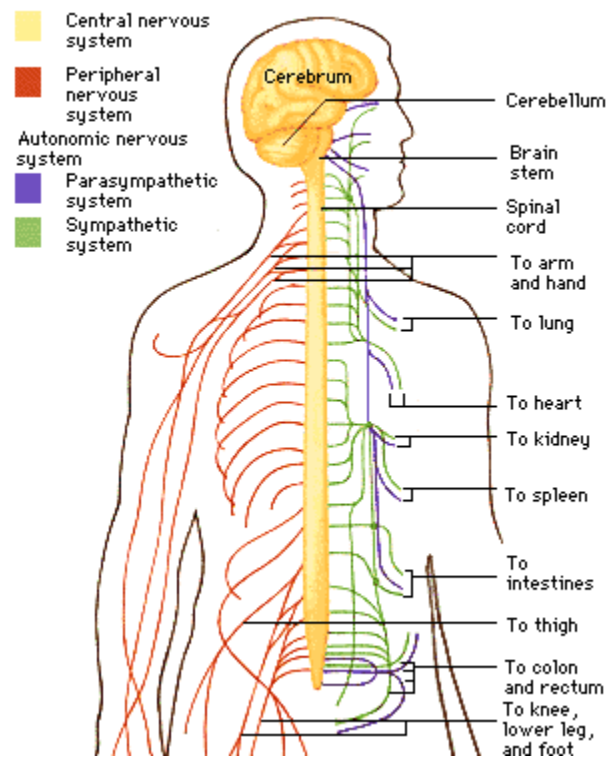
Cerebral Palsy is described as a group of chronic disorders of movement control that is associated with non-progressive brain defect or injury acquired during gestation or early in development (Cheney and Palmer 1997). Because Cerebral Palsy results from brain defect, it is important to discuss the multiple parts of the nervous system that can be affected. The nervous system is associated with response to stimuli and is comprised of the brain and spinal cord, as well as all of the nerves in the body. It is divided into two sub systems: the central and peripheral nervous systems. The Central Nervous System includes the brain and spinal cord, while the Peripheral Nervous System includes the rest of the nerves in the body (Figure 5).

### Cerebrum:

The human brain has three main parts, namely the cerebrum, the cerebellum and the brain stem (Figure 6). The first section, the cerebrum, is the largest part of the brain and is divided into two cerebral hemispheres, which are separated by the deep sagittal fissure, and which control opposite sides of the body. The cerebral hemispheres account for about 83% of the total brain mass (Marieb 2004). Each hemisphere has three basic regions: the cortex, the internal white matter and the basal ganglia. The cerebral cortex is located at the surface of the brain, is composed of grey matter, and consists of neuron cell bodies, dendrites and unmyelinated axons, but does not contain any fiber tracts. It is divided into four lobes, which are named after the bones of the skull that lie over them:

the frontal lobe, parietal lobe, temporal lobe, and occipital lobe (Figure 7) (Bear et al. 2001). The white matter is internal to the cortex and consists of myelinated fiber tracts. The basal nuclei or basal ganglia, are located deep within the white matter (Marieb 2004).

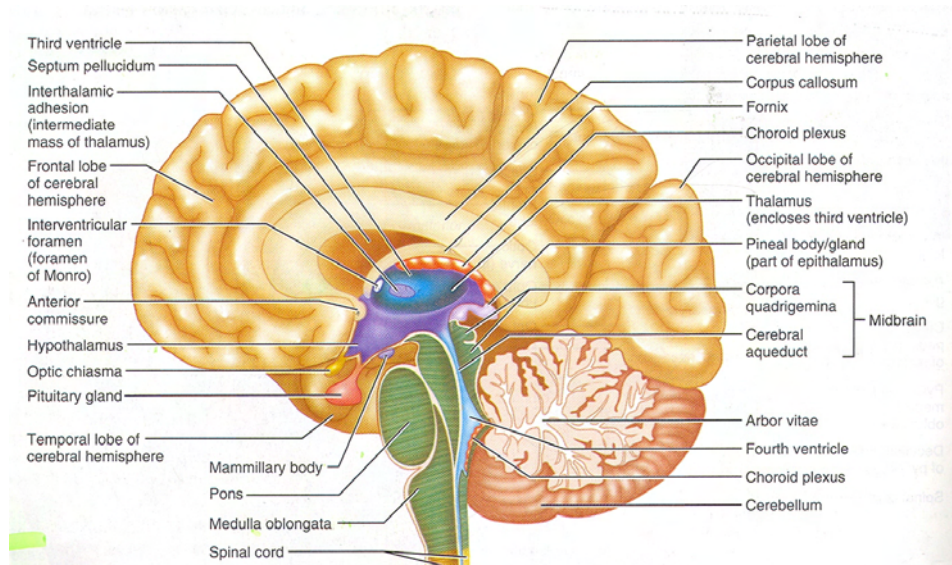
Figure 5: Central and Peripheral Nervous Systems



(Divisions of the Nervous System . Retrieved April 19, 2007, from Think Quest Web site:  
<http://library.thinkquest.org/28807/data/nervous2.htm>)

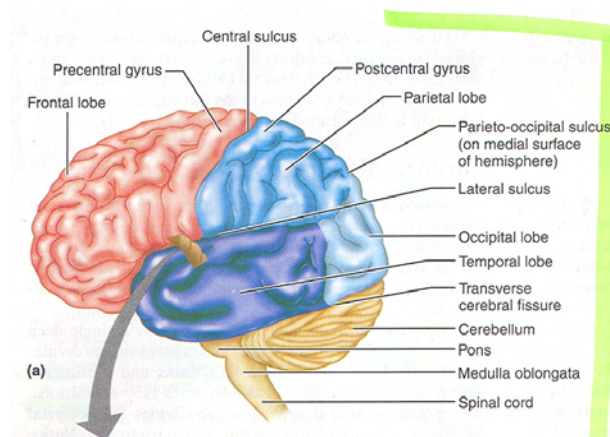


**Figure 6: Anatomy of the Brain**



(Marieb 2004)

**Figure 7: Lobes of the Cerebrum**

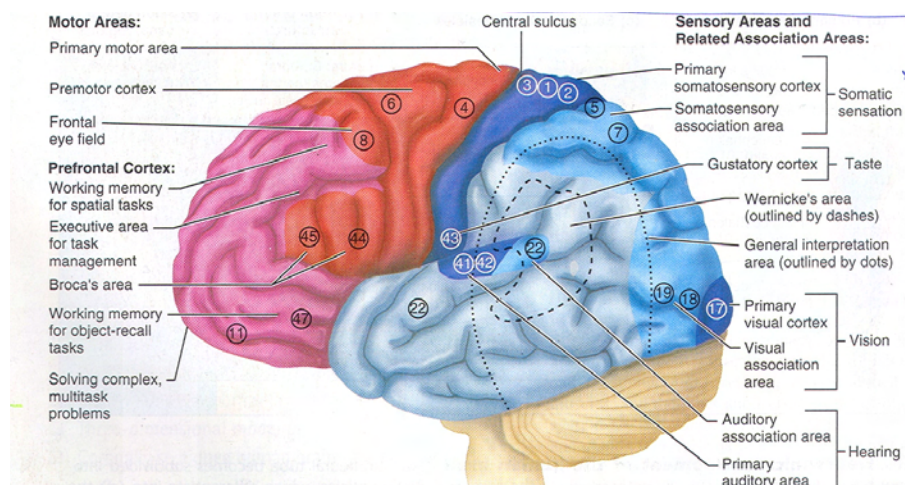


(Marieb 2004)

## Cerebral Cortex

Understanding the function of the cerebral cortex is essential to understanding the pathology involved in Cerebral Palsy, as this is where most of the planning and initiation of motor skills occurs. Sensory information from the spinal cord impinges on the cerebral cortex, where it is processed and transformed into motor output or perception information (Heimer 1995). Indeed, the cerebral cortex is responsible for recognition of all sensations, and allows for communication, memory, and initiation of voluntary movements (Marieb 2004). The cortex is divided into three major areas, each of which is further subdivided: motor areas, sensory areas, and association areas (Figure 8). All of these areas work together to use sensory information to produce a motor response and to allow for recognition of all sensations, communication, and memory formation (Nolte 1999).

**Figure 8: The Cerebral Cortex**



(Marieb 2004)

The motor areas of the cortex control voluntary movement and are located in the posterior part of the frontal lobes. The primary motor cortex is located in the precentral gyrus and contains large neurons called pyramidal cells that enable voluntary control of movements (Marieb 2004). The premotor cortex lies anterior to the precentral gyrus in the frontal lobe, and is responsible for controlling learned motor skills that tend to repeat or are patterned in nature, such as walking. Broca's area controls motor skills associated with speech and is located anterior to the premotor area. What is unique about this area, unlike the other motor areas, is that it is usually only located in one hemisphere (Marieb 2004). Finally, the frontal eye field controls the voluntary movement of the eye and is located anterior to the premotor cortex and superior to Broca's area (Marieb 2004).

There are seven sensory association areas in the brain that contribute to sensory integration and that receive sensory information from the peripheral nervous system. The first area is the primary somatosensory cortex, which is located in the post central gyrus of the parietal lobe (Marieb 2004). This area receives information from sensory receptors in the skin and from proprioceptors in the muscles, and is the first relay station for sensory information on its way into the brain (Marieb 2004). Just posterior to the primary somatosensory cortex is the somatosensory association cortex, which integrates sensory information from the primary somatosensory cortex (Marieb 2004). From here, sensory information is sent to a specific area of the brain, depending on the type of sensory information. Visual information is sent to the striate cortex and the visual associate areas, while auditory information is sent to the primary auditory cortex and the auditory association area. Information about smell is sent to the olfactory cortex, while

taste information is sent to the Gustatory cortex. Finally, vestibular information, or information concerning balance and physical location in space is sent to the vestibular cortex (Marieb 2004).

Association areas allow communication with the motor cortex and with other areas of the cortex in order to produce the motor response. Each area receives specific types of sensory information, processes it and sends it to yet another area of the brain for further processing. The areas to which the information is sent are completely independent of the association areas already mentioned. These areas, that receive information from the association areas, include the prefrontal cortex, which functions in intellect, learning and recall, and the language areas that integrate language information and allow for comprehension of hearing. The part of the brain which functions for general encoding is found in only one hemisphere, receives input from all sensory association areas, and integrates it into a single signal (Marieb 2004).

The cerebral cortex is also involved in cognition and thoughts, as well as in the elaboration of learning memory and language (Heimer 1995). Overall, the cerebral cortex is responsible for receiving sensory information and transmitting it to the right areas of the brain so that it may be processed into some form of output.

### Cerebral White Matter

The cerebral white matter is located deep to the cerebral cortex, and is responsible for communication between the motor, sensory and association areas of the cerebral areas and between the lower central nervous system structures. The cerebral white matter is

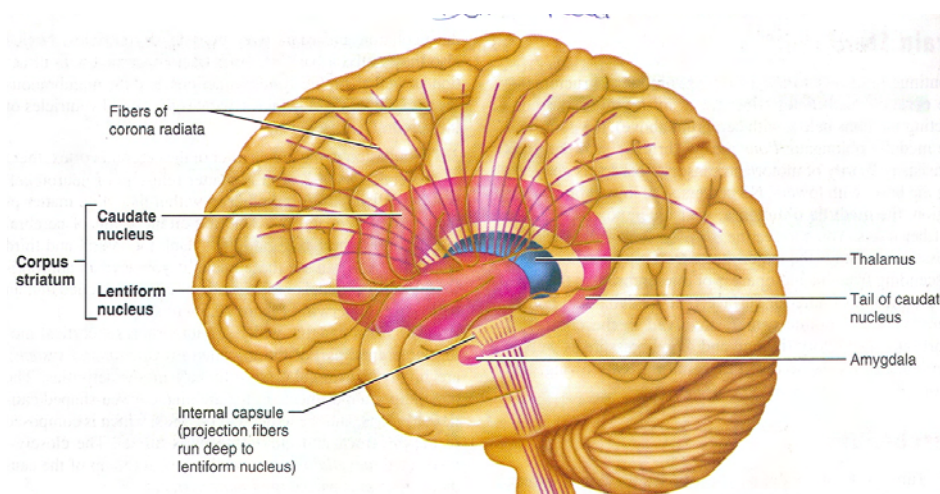
primarily made of large tracts, or commissures, which are composed of myelinated fiber bundles. Commissures function to connect corresponding areas of the cerebral cortex and the two hemispheres, which enables both sides of the brain to function together as one unit (Marieb 2004). The largest of these commissures is the corpus callosum, which lies in the middle of the two hemispheres and acts to connect the entire right hemisphere with the entire left hemisphere. Association fibers function within each hemisphere, as they connect various parts of the same hemisphere (Marieb 2004). Finally, projection fibers connect the cerebral hemispheres to other parts of the brain. They receive information from the lower brain or spinal cord as well as send information from the cortex to the rest of the brain (Marieb 2004). Overall, the cerebral white matter functions to connect cerebral structures with the rest of the nervous system.

Another structure of the brain that acts as a relay station for information to and from the cerebral cortex is the thalamus. The thalamus, which is not actually a part of the cerebral white matter, is located deep to the cerebral white matter in the diencephalon. The thalamus is part of a large number of pathways that connect the cerebral cortex to other structures in the brain, including the basal ganglia and cerebellum. The thalamus is divided into many nuclei; each of which has a separate function that will not be described here, that are used to process different types of information. Indeed, the thalamus plays a critical role in relay of information both to and from the cerebral cortex (Nolte 1999).

## Basal Ganglia

Located deep to the cerebral white matter are the basal ganglia, which function as a relay station between the cortex and other areas of the brain and the spinal cord (Figure 9). The basal ganglia consist of four different parts including: the caudate nucleus, the putamen, the globus pallidus and the subthalamic nucleus. Together, the caudate and putamen form the striatum, which is the target of input to the basal ganglia (Bear et al. 2001). Through various relays in the thalamus, output from the basal nuclei is sent to the premotor and prefrontal cortices to cause movements, which are directed by the primary motor cortex. The overall function of the basal nuclei is to initiate, stop, and monitor movements executed by the cortex, primarily movements that are slow or predictable (Heimer 1995). In addition to the control of slow movements, the basal nuclei also inhibit unnecessary or antagonistic movements (Marieb 2004).

Figure 9: The Basal Ganglia



(Marieb 2004)

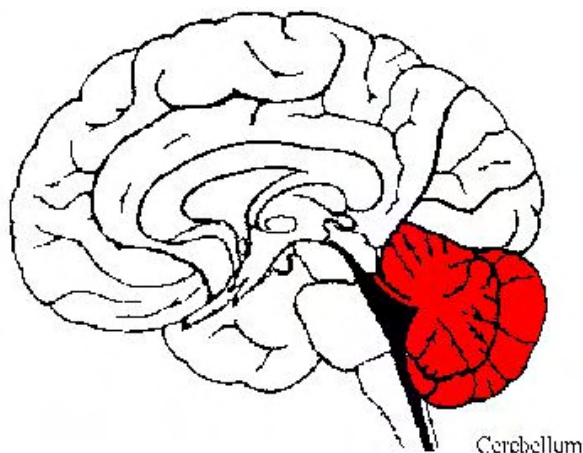
### The Cerebellum:

Located ventrally and posteriorly to the cerebrum is the cerebellum (Figure 10). The structure of the cerebellum is similar to that of the cerebrum. Like the cerebral cortex, the cerebellar cortex covers several deep nuclei that act as relay stations for many different types of information.

The primary function of the cerebellum is to process information from the cerebral motor cortex as well as from proprioceptors located in the muscles and joints, and visual and equilibrium centers (Heimer 1995). The cerebellum also plays a role in cognition, learning, creating motor programs and motor memory as well as problem solving (Heimer 1995).

Movement control by the brain can be thought of hierarchically, with high, middle, and low centers of control. The high brain centers, such as the cortex, basal ganglia and forebrain, are concerned with strategy, while the middle centers, including the motor cortex and cerebellum, are concerned with the tactics and mechanics necessary to carry out the movement. Finally, the lower brain centers, the brain stem and spinal cord, are involved with execution of the movement (Bear et al. 2001).

Figure 10: The Cerebellum



(What does the Cerebellar Vermis Look Like? . Retrieved April 19, 2007, from Medfriendly.com Web site: <http://www.medfriendly.com/cerebellarvermis.html>)

### The Brain Stem:

The brain stem consists of three structures, namely the midbrain, medulla oblongata and pons and is located just under the cerebral hemispheres at the posterior portion of the brain. It serves as a relay station for information from the cerebrum to the spinal cord and cerebellum and from the cerebellum to the cerebrum (Bear et al. 2001).

The second structure of the brain stem, which lies just behind the cerebellum, is the midbrain. The midbrain contains many nuclei that act as relay stations for different types of sensory information. Many of these nuclei also direct processing of some reflex information that does not need to be processed in the higher areas of the brain. The pons also acts as a relay station for information to and from the higher brain and contains centers that control normal breathing rhythms (Marieb 2004).



The medulla oblongata, or medulla, is located closest to the spinal cord (Nolte 1999). This part of the brain stem is connected directly to the spinal cord and contains many nuclei which act as relay stations for various types of information. The medulla also contains centers important in controlling cardiovascular and respiratory function. Various other centers are also located in the medulla, which regulate vomiting, hiccupping, swallowing, coughing and sneezing (Marieb 2004). Overall, the medulla functions to relay many types of information, as well as to control regulation of various vital functions.

#### The Brain and Cerebral Palsy:

While much is known about the brain and the structures that contribute to its myriad functions, it is often difficult to define exactly where the brain injury and or defect lies in Cerebral Palsy and consequently to understand the physical implications associated with such a deformity or injury. It is known, however, that most cases of CP originate from damage the cortex, basal ganglia and thalamus (Folkerth 2005).

Neuroimaging studies have been completed to find correlations between the types of Cerebral Palsy and the areas of brain damage. One study found white matter abnormalities in 43% of all Cerebral Palsy cases, but more specifically in 71% of children with diplegia, 34% of children with hemiplegia and 35% of children with quadriplegia. Other studies have found 13% of cases to have some damage to the basal ganglia, and 9.1% of cases have overall malformation of the brain, while 9.4% have cortical-

subcortical abnormalities. Furthermore, of the children with basal ganglia injuries, 76% had dystonia, or irregular muscle tone (Msall 2006).

Another study, completed by Yokochi (2003) used magnetic resonance imaging (MRI) to evaluate brain damage associated with Cerebral Palsy. The study found some cases of Cerebral Palsy to be caused by damage to the thalamus, putamen (part of the basal ganglia), and peri-Rolandic area. The study compared the level of disability in children with Cerebral Palsy and evaluated the location and depth of the lesions in the brain. It was found that children with damage in all three of these areas had the most severe disabilities in areas of gross motor, fine motor and mental development. On the other hand, children with damage to only the thalamus and putamen or only the thalamus had mild disabilities.

Finally, Cerebral Palsy can also be a result of damage to the cerebellum. A study completed by Johnsen et al. (2005) evaluated the frequency and variable nature of magnetic resonance imaging (MRI) that documented injury to the cerebellum in children with Cerebral Palsy. Thirty of the 67 patients evaluated were found to have injury to the cerebellum, based on MRI results. Of the 37 patients who did not endure injury to the cerebellum, 78% had injury to the cerebellar white matter. This study shows that damage to the cerebellum is common in children with Cerebral Palsy (Johnsen et al. 2005).

The direct causes of Cerebral Palsy are difficult to understand because of the complex structure of the brain and its many networks. Therefore, it is still to be determined what type of damage to what areas of the brain are responsible for a particular

presentation of Cerebral Palsy. Further research should elucidate the outcomes of brain damage, including symptoms of Cerebral Palsy.

### **Chapter III: Hip Pathology in Cerebral Palsy**

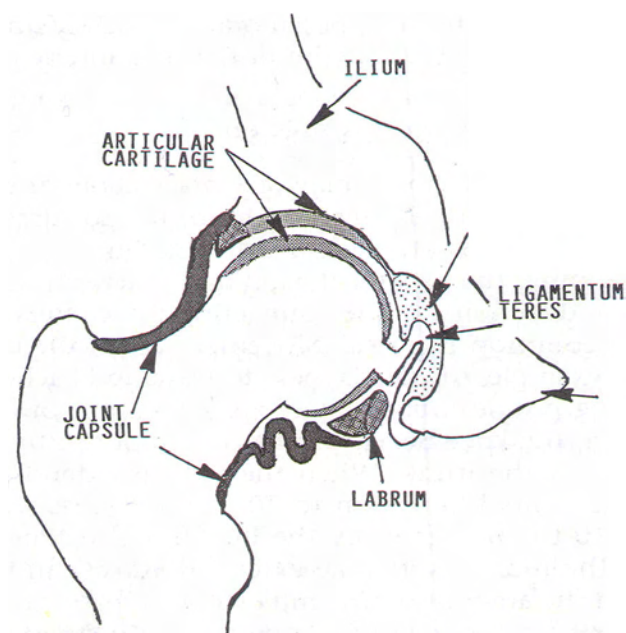
The hip plays an important role in stability and mobility. In CP, the patients' hip is often unstable due to spasticity and contractures of the muscles surrounding the hip. This instability can cause abnormal gait or the inability to walk. This chapter will discuss the basic anatomy of the normal hip as well as possible pathologies associated with CP.

#### **Basic Structure and Function of the Normal Hip:**

The hip is a ball and socket joint, which allows for three degrees of freedom and a wide range of motion (Marieb 2004). Movements at the hip occur in all planes and include: flexion and extension, adduction and abduction, as well as inward and outward rotation. Muscles involved in flexion of the hip include the iliopsoas, the rectus femoris, sartorius and tensor muscles, while extension of the hip is controlled by the gluteus maximus, biceps femoris and semimembranosus, and semitendinosus, as well as other adductor muscles. Hip adductors include: adductor magnus, adductor longus, adductor gracilis, adductor brevis and pectineus, while the hip abductors are the gluteus medius, gluteus minimus, tensor fasciae latae, and the upper fibers of the gluteus maximus (Smith et al. 1996). The sartorius, piriformis and obturators can also assist in abduction. Many of the muscles listed above are also involved in rotation of the hip, but their actions depend on the position of the hip joint in reference to flexion, extension, abduction and adduction. The six external rotators are the piriformis, gemellus superior, gemellus inferior, obturator internus, obturator externus and the quadratus femoris (Smith et al. 1996).

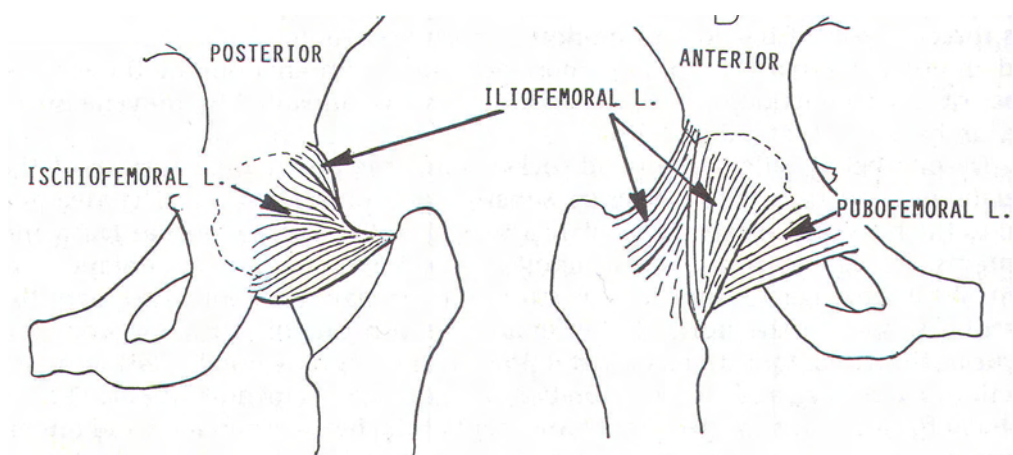
Despite its impressive mobility and the numerous muscle involved in hip mobility, the hip joint is somewhat limited by ligaments and the amount of articulation between the head of the femur and the acetabulum (Smith et al. 1996). The head of the femur fits snugly inside a cup shaped socket called the acetabulum (Figure 11), lined with the acetabular labrum, which is a circular rim, made of fibrocartilage (Merriam-Webster 1995). The acetabular labrum increases the stability of the hip joint, but slightly decreases the range of motion (Marieb 2004). Furthermore, several ligaments act to stabilize the hip joint (Figure 12). The iliofemoral ligament, or the Y ligament lines the hip on the anterior and superior side, and wraps from the front of the hip to the back (Smith et al. 1996). This ligament prevents hyperextension and limits adduction. The pubofemoral ligament is located on the anterior and inferior side of the hip and limits external rotation and abduction. The ischiofemoral ligament is located posteriorly and inferiorly. It acts to limit internal rotation as well as abduction of the hip. Finally, the ligamentum teres is located inside the joint capsule and functions to provide the blood supply to the head of the femur (Fagerson 1998). Overall, the hip provides stability and support for the lower extremity. However, in patients with CP, this function can be disrupted. In many patients with Cerebral Palsy, the ligaments that support the hip and maintain the position of the femoral head in the acetabulum are weakened due to contractures of the muscles supporting hip movement. These contractures pull the femoral head out of the acetabulum and put pressure on the surrounding ligaments, causing them to stretch and become weakened. Weakness in these ligaments can lead to hip subluxation and eventually dislocation.

Figure 11: Acetabulum



(Smith et al 1996)

Figure 12: Ligaments of the Hip



(Smith et al. 1996)

### Dislocation:

For patients with Cerebral Palsy, hip dislocation is a common problem. Incidence of hip dislocation varies with the specific presentation of Cerebral Palsy. It is estimated that 7% of ambulatory patients (who are able to walk independently) experience hip dislocation and that 60% of patients with quadriplegia will experience some degree of hip dislocation (Hagglund et al. 2005). Indeed, it has been found that children with mild involvement, who are ambulatory, are less likely to experience hip dislocation than patients who are non-ambulatory and quadriplegic (Soo et al. 2006). Hip dislocation occurs when the head of the femur is removed from the acetabulum, and is usually the result of spasticity and contracture of the hip adductors and flexors and the medial hamstrings (Figure 13) (Soo et al. 2006).

Figure 13: X- Ray of Hip Dislocation



(Feldman 2006)

There are two types of dislocation: anterior and posterosuperior. The types of dislocation are defined by the direction in which dislocation occurs: anterior dislocation occurs towards the front of the body, while posterosuperior dislocation occurs toward the back and up (Giuseppe et al. 1998). Anterior dislocation is less common, but can cause a wide range of problems for the patient such as sitting difficulty and hip pain, as well as difficulty in perineal care (Giuseppe et al. 1998). Anterior hip dislocation is generally caused by severe abduction or adduction of the hip, as well as over lengthening of adductors and hip flexors with interventions such as extension cast immobilization. This pattern is rarely seen in the ambulatory patient, and is more likely experienced by patients that have severe quadriplegic Cerebral Palsy with extension posturing or severe hypotonia. This type of dislocation is rare and there are very few treatments for this type of location (Giuseppe et al. 1998). However, some treatments are available, especially for young patients and will be discussed later.

The second type of dislocation, posterosuperior dislocation, is more common, and may cause pain, pelvic obliquity, difficulty sitting, standing or walking, poor trunk balance, poor perineal care, as well as contractures, fractures, skin ulceration and scoliosis (Hagglund et al. 2005). Posterosuperior dislocation is generally caused by persistent muscle imbalance, as well as flexion contracture of the hip and adduction (Giuseppe et al. 1998). This combination of pathologies causes progressive femoral-head and acetabular deformity, which results in posterosuperior dislocation, which can cause the symptoms listed previously.



Both anterior and posterosuperior dislocation have long-term implications. The most frequent problem encountered is difficulty in sitting and positioning (Raymond 2002). Furthermore, older patients with Cerebral Palsy will continue to experience adduction contracture, which limits perineal care. Finally, pain will continue to increase as the condition worsens over time.

There are many treatments for both types of hip dislocation, including physical therapy, botulinum toxin injections, selective dorsal rhizotomy, soft tissue surgery such as tendon lengthening, as well as osseous procedures, which involve rearranging bone structure (McClure 2005). These treatments will be discussed in detail, along with mechanisms of diagnosis and treatment planning, in the next chapter.

#### **Chapter IV: Treatments of Musculoskeletal Symptoms in Cerebral Palsy**

As discussed earlier, symptoms of Cerebral Palsy are primarily musculoskeletal and include: spasticity, dystonia (athetosis), muscle contractures, low muscle tone, abnormal bone growth, as well as difficulty with balance and coordinating movements (Gormley 2001). These symptoms lead to many possible treatment combinations that depend on the individual and his or her needs. However, one approach remains consistent: treatment must be interdisciplinary and it must begin as early as possible.

As children develop, they continually make changes and their brains are most plastic earlier in life, so early stimulation is critical to developing motor patterns and proper brain architecture (Gormley 2001). Also, as patients grow older, the frequency of contractures, joint subluxation, dislocation or deformity and body deformity increases (Koman et al. 2004). Because of these developmental concerns it is important to begin treating Cerebral Palsy as soon as possible.

##### Initial Treatment and Gathering Resources:

The first step in developing a treatment is to gather a team that includes a primary care physician, a physiatrist, a neurologist, a gastroenterologist, a pulmonologist, an orthopedic surgeon, teachers, social workers as well as occupational, speech and physical therapists and parents. Together, these professionals can develop a strategy that includes goals and treatment plans for the patient (Dabney et al. 1997). Communication between the team members is critical to establishing the best strategy for the patient that will insure the best possible care (Dabney et al. 1997).

Once established, the team will begin goal setting. Goals must span the patient's life, and are always focused on optimizing function and integrating the patient into society. The first stage of treatment is physical therapy, which is usually the only treatment until the age of three. After age three other opportunities for treatment become more available. The physical therapist is the primary resource center for the parents and acts as the "goal setter." The ideal time for orthopedic intervention, if necessary, is age three. Between the ages of seven and eighteen, education and psychosocial interventions are the most important. Finally, when the patient becomes an adult, the team begins to focus on integration into the workforce, marriage and residential issues (Dabney et al. 1997). Throughout the process, it is important to set priorities, as all concerns cannot always be addressed due to resource limitations.

Many parents often agree that walking should be a primary goal for their child. However, many professionals acknowledge that walking may not always be possible and have set a list of priorities, that present communication as being the most important, followed by activities of daily living, mobility in the environment (whether through gait or another adaptive device such as a wheelchair), and walking. Once a team has been developed, and priorities and goals have been established, treatment can begin (Dabney et al. 1997).

There are multiple types of treatment for the musculoskeletal symptoms of Cerebral Palsy including: physical therapy, casting, orthotics and bracing, medication, as well as many types of surgical interventions (DeLuca 1996).

### Physical Therapy

Physical therapy is critical to early intervention and focuses primarily on range of motion of the joints to prevent contractures, and teaching families how to implement a home program. Teaching patients and parents how to continue therapy at home is one of the most important aspects of physical therapy. Most families cannot afford the enormous expenses of everyday therapy, so it is important to continue therapy at home as often as possible to insure the best quality of life for the patient (DeLuca 1996).

### Casting, Bracing and Orthotics:

In addition to physical therapy, casting may also be done to increase range of motion through prolonged stretching. It has been shown that temporary casting can be very beneficial in reducing muscle tone and contracture and is most evident at the ankle, as it has the potential to reduce toe walking (DeLuca 1996). Braces and other orthotics may also be used to help delay the development of contractures, and to limit stretch-induced clonus, or rapid flexion and extension of a particular muscle group, and decrease the consumption of energy by making movement more efficient. The most common form of orthotic is the Ankle Foot Orthotic, or AFO, which keeps the ankle in a neutral position and prevents dorsiflexion and plantarflexion. However, braces that spread the hips, and hip abduction orthoses may also be prescribed to prevent hip subluxation. Sometimes, braces that extend above the pelvis are needed to prevent scoliosis and contracture of postural muscles. Overall, braces provide joint stability and support,

prevent contractures, and provide movement support to increase the efficiency of movement.

#### Pharmaceutical Interventions:

Pharmaceutical medication may also help some of the symptoms associated with Cerebral Palsy. Various medications may be given orally or intramuscularly in order to manage spasticity (Koman et al. 2004). With the exception of botulinum toxin A and intrathecal baclofen (a common muscle relaxant), most medications are not given to children. Botulinum toxin A is known to temporarily reduce spasticity and to temporarily improve fine motor function (Reddibough et al. 2002). Treatment involves injecting botulinum toxin A (a toxin produced by the gram –positive *Clostridium botulinum* bacterium) (Dabney et al. 1997), into spastic muscles to balance muscle forces across a joint, and is generally effective for 3-8 months (Koman et al. 2004). Other injections to relieve spasticity include alcohol and phenol injections, which produce responses similar to botulinum toxin A. Finally, intrathecal baclofen may be used in conjunction with dorsal rhizotomy (a procedure in which spinal nerve roots are cut to decrease pain) to manage more widespread spasticity.

#### Surgery:

Aside from physical therapy, casting, braces and orthotics, and pharmaceutical medications, other more invasive procedures may be performed for certain symptoms of Cerebral Palsy. Neurosurgery, of which the selective posterior/dorsal rhizotomy is the

most popular, involves invasive surgery of the central nervous system. This procedure involves performing a lumbar laminectomy (surgical removal of bony arches on one or more vertebrae) and then localizing the dorsal rootlets into the cauda equina, or the end of the spinal cord (Gormley 2001). Then, the dorsal roots of the L1-S2 region of the spinal cord are tested and cut if an electrical stimulus to the root initiates contraction of a muscle that the root would not typically innervate. Another form of neurosurgery is the insertion of an intrathecal baclofen pump, which involves inserting a pump into the abdomen and then attaching a catheter into the intrathecal space of the spinal cord, or just outside of the cord. The pump delivers baclofen, a drug that is known to reduce spasticity, to the lumbar region of the spinal cord. Neurosurgery tends to be risky and very invasive, and is not as common as orthopedic surgery, which aims to correct bone, joint and muscle structure and function.

Orthopedic surgery is the most common form of surgery for Cerebral Palsy and is known to be the best treatment for significant musculoskeletal problems. Types of surgery include: tendon lengthening, neurectomy or removal of a nerve, tenotomy or the cutting of a tendon, arthrodesis or permanent immobilization of a joint, osteotomy or division of a bone, ostectomy, or excision of part of or an entire bone, tendon transfer or relocation of the origin and insertion of a tendon, tendon lengthening, or the release of a tendon in order to make it longer, fractional myotendinous lengthening, which is similar to tendon lengthening, multisegmental spinal fusion, which involves joining two or more vertebra using metal rods or screws, or a combination of these procedures (Koman et al.

2004). Many orthopedic surgery interventions are used to ease problems associated with hip subluxation and dislocation (Gormley 2001).

Hip dislocation, as mentioned previously, is a common problem in patients with spastic Cerebral Palsy, and is caused by spasticity and contracture of the hip adductor and flexor musculature (Dabney et al. 1997). Hip subluxation and dislocation can occur in both ambulatory and non-ambulatory patients, but is more common in non-ambulatory patients. However, the treatment is the same for both types of patient. Prevention of subluxation or dislocation is the primary treatment, and requires surgical release of the involved muscles, usually the adductor and iliopsoas. If treatment is not initiated to prevent subluxation of the femoral head, further surgery is inevitable as bracing, casting and physical therapy are no longer options after subluxation begins.

One of the most common treatments for hip subluxation, and later dislocation, is the femoral derotation osteotomy. This procedure is simple, but involves a lengthy and painful recovery. Whether the treatment should be initiated is a difficult question that many parents of children with CP must face. Many risk factors must be considered before parents decide to initiate surgery. A description of the risk factors, as well as the indications for treatment and an overall analysis of this surgery are described in the following chapters, designed to help parents make the best possible decision for their children.

## **Chapter V: The Femoral Derotation Osteotomy**

### Indications for Surgery:

In patients with Cerebral Palsy, as many as 80% with spastic diplegia develop subluxation, which can lead to hip dislocation. This is often painful and can lead to assymetry and pelvic obliquity, which can cause sitting imbalance. If the hip becomes dislocated, the muscles that promote movement around this hip can become contracted, which contributes to persistent dislocation. Many factors must be evaluated before a patient can undergo a femoral derotation osteotomy- the most common treatment for hip dislocation in Cerebral Palsy. These factors include pain, location of pain, possible limp and presence of joint congruency. First, the level of pain is evaluated and usually found to be activity related. Second, the location of pain is evaluated. The pain is most commonly in the groin, thigh and buttock and is caused by extended periods of sitting or standing. Finally, presence of a limp and joint congruency between the hips are evaluated. If there is a loss of joint congruency, or symmetry between the joints, the indications for surgery may change (Feldman 2006).

After these initial parameters are evaluated and it seems that there might be indications for surgery, it must be determined whether the problem is femoral or acetabular or both (See Chapter 4), as these problems may be indications for surgery. Finally, it is necessary to evaluate if the joint can be reduced, or replaced in its normal position inside the acetabulum. If the joint cannot be reduced, a femoral derotation osteotomy is not recommended.



After determining that the joint can be reduced and surgery is needed, it is necessary to evaluate the degrees to which the hip must be externally rotated. A subluxed or dislocated hip is prone to dislocation due to the fact that the hip is internally rotated and must be returned to the reduced, or neutral position. It may also be necessary to evaluate the degree of spasticity or contractility of the muscles surrounding the hip and discuss possible soft tissue procedures to release the tension placed on the joint. Once all these factors are carefully evaluated, an outline of goals for surgery is produced, as a derotation osteotomy is often combined with other types of orthopedic surgery (Feldman 2006).

#### Goals of Surgery:

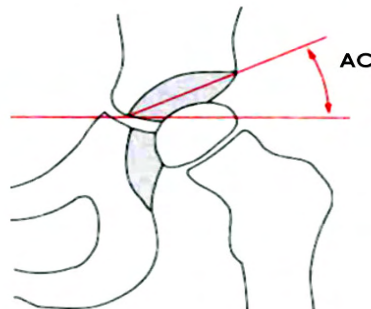
The primary goal of any operation at the hip is symmetry. Symmetry improves function by insuring that agonist and antagonist muscles are allowed to act complementarily. The second goal is to protect the joint from further injury, such as avascular necrosis (lack of blood supply to the femoral head). The third goal is to minimize strength loss, and reduce joint contact pressures in order to produce a stable, painless joint that maintains a functional range of motion. The fourth and final goal is early return to standing position and ambulation. The above listed indications and goals should be carefully considered before performing a femoral derotation osteotomy (Feldman 2006).

### Reasons to Maintain a Reduced Hip:

There are several reasons for maintaining the hip in the reduced, or relocated position, including biomechanical efficiency, balance, pain management, functional range of motion and stability. The first reason is that when the hip remains in the acetabulum, biomechanics are improved, which in turn produces greater energy efficiency, which improves ambulation. Second, in more involved patients, a repositioned hip improves balance in sitting, which is important for eating and allowing the individual better use of the upper extremity. Pain can also be reduced and prevented after recovery from a derotation osteotomy (Hoffer et al. 1985). Range of motion at the hip joint is also increased when the hip remains reduced. In a study completed by Root et al. (1995), it was found that the average flexion of the subluxed or dislocated hip was  $123^{\circ}$ , extension was  $-20^{\circ}$  and abduction was  $25^{\circ}$ . The normal values for these measurements are  $70-90^{\circ}$  for hip flexion,  $28^{\circ}$  for hip extension, and  $45^{\circ}$  for abduction (Smith et al. 1996). Subluxation and dislocation also affect internal and external rotation of the hip. These values normally decrease with age, but a greater decrease is seen in the pathological hip, as this range of motion is often limited. Normal external rotation for a five year old is about  $60^{\circ}$  (with knee flexion),  $20^{\circ}$  without, while internal rotation is about  $55^{\circ}$  (with knee flexion), and  $25^{\circ}$  without. A study completed by Hayong et al. (2005), found that external rotation previous to the operation was about  $10.7^{\circ}$ , while internal rotation was  $77.7^{\circ}$ . These values indicate the extreme differences in hip mobility of patients with CP compared to normal patients.

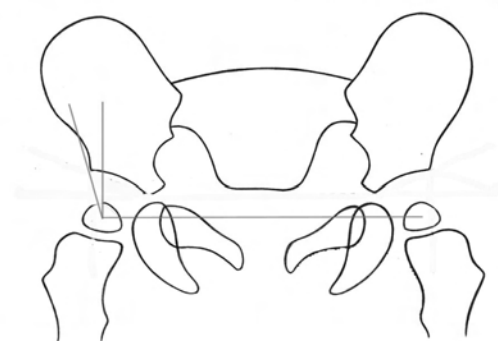
Hip stability is also affected by dislocation, and Root et al. (1995), also found that on average, preoperative acetabular angle was  $50^{\circ}$  (Figure 14), the center-edge angle was  $-19^{\circ}$  (Figure 15) and the migration index was 74% (Figure 16). Overall, many indications influence the decision regarding the need for a femoral derotation osteotomy, including improvement of biomechanics for walking and sitting, reduction in pain caused by hip dislocation, and subluxation, and improved range of motion and hip stability. Once an orthopedic surgeon examines these indications, treatment can begin.

Figure 14: Acetabular Angle



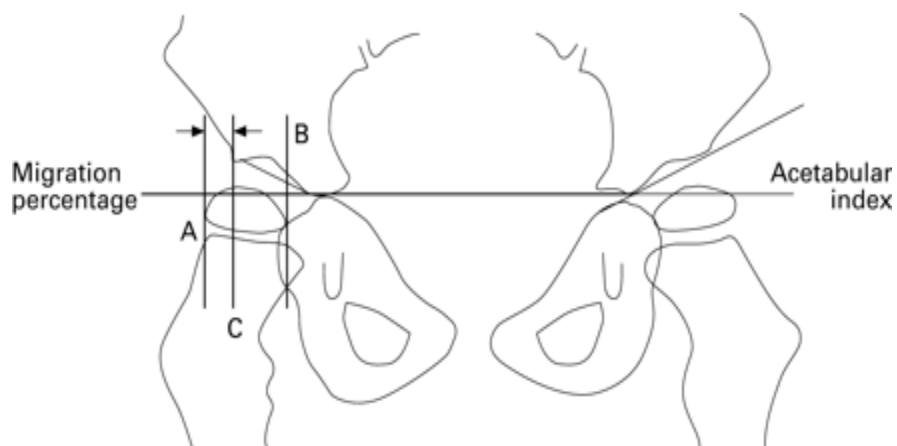
(Acetabular Angle . Retrieved April 19, 2007, from Acetabular Angle Web site: <http://bmc.ub.uni-potsdam.de/1471-2431-5-17/F2.htm>)

Figure 15: Center-Edge Angle



(ohsu.edu . Retrieved April 19, 2007, from Center Edge Angle Web site:  
<http://www.ohsu.edu/radiology/teach/kojima/hip.htm>)

Figure 16: Migration Index



(Scrutton and Baird 1997)

### Description of Procedure:

The femoral derotation osteotomy is a hard bone procedure that involves severing the femoral head and repositioning it inside the acetabulum in order to prevent further subluxation or dislocation, and to decrease pain associated with dislocation (Hoffer et al. 1985). The procedure begins with a skin incision that exposes the femur. Then, using a saw, the surgeon makes guide holes through which the bone will be repositioned. Next, the femur is cut horizontally to the leg, and the distal portion of the femur is externally rotated the desired degree. Finally, the bone is fixed in its new position using slotted plates (Figure 17) (Glessner 1967). In essence, the shaft of the femur is separated from the head of the femur, allowed to twist, then reconnected to the head, which remains anchored in the acetabulum. When the procedure is completed the patient is placed in a spica cast that must be worn for six to eight weeks (Figure 18) (Hoffer et al. 1985).

Figure 17: Bony Plates in Place



(Feldman 2006)

Figure 18: Hip Spica Cast



(What is a Spica Cast? . Retrieved March 5, 2007, from SpicaCast.com Web site:  
<http://www.spicacast.com/>)

Spica Cast Complications:

In recent years, it has been found that many complications are associated with the use of spica casts, including ulcers in areas prone to high pressure, restricted chest movement resulting in respiratory complications, difficulties with feeding, toileting and overall general care (Wilkinson et al. 2001). These complications have led to many studies on other recovery techniques that do not require a hip spica cast. A study completed by Wilkinson et al. (2001), described a new technique that involves using a Richards' intermediate hip screw as opposed to a fixed angle blade plate during the femoral derotation osteotomy. The Richards' intermediate hip screw was found to enhance stability of the hip after the operation by using a second point fixation at an

angle that would provide a “crossed fixation construct” (Wilkinson et al. 2001). Previous derotation osteotomy techniques used a side plate for an intermediate hip screw which contained three holes: one proximal and one distal, all of which were used for fixation of the side plate to the femoral shaft. These plates were placed along the outside of the femur and attached using three screws in the mentioned areas. In the technique developed by Wilkinson et al (2001), the proximal slot is used as a secondary point of fixation for the proximal femur rather than the femoral shaft. Using this technique, which only uses two screws as opposed to three that are anchored closer to the hip joint, only two out of twenty patients needed a hip spica cast to maintain stability during recovery. One of the patients requiring a spica cast had severe osteopenia (reduction in bone mass), while the other endured many soft tissue procedures that required the cast. This study shows a significant drop in the number of spica casts needed from 61% to 16%. Overall, it was found that this technique increases the stability of the hip after surgery and decreases the need for hip spica casts. However, there are also many other techniques to be considered and each orthopedic surgeon may use the one that seems most appropriate. Orthopedic surgeons may also differ in opinions on the age at which the operation should be completed.

#### Optimal Age:

Many studies have attempted to determine the age at which the femoral derotation osteotomy provides the best outcome. Glessner (1967) recommended that older children were more likely to benefit from the procedure, but current research indicates that the

best results are seen in children under eight years of age. Kasser et al. (1985), found consistently good results in patients who were younger than four years old at the time of the operation, but that hip dysplasia remained persistent in children ages four to eight years. Overall, they found that the procedure was less predictable in children over eight years of age. Another study, completed by Svenningsen et al (1989), suggests that the procedure is too risky to be completed at such a young age, and does not always accomplish the intended goals. Due to the high risks, this study recommends that children be followed until twelve years of age before considering a derotation osteotomy (Svenningsen et al. 1989). Overall, scientists and physicians still disagree about the ideal age at which to perform the derotation osteotomy. However and regardless of the child's age, this procedure remains indicated for patients experiencing pain associated with severe subluxation or dislocation.

#### Post Surgery Assessment:

After the procedure, rehabilitation and therapy are extremely important. A study conducted by Stasikelis (2003) that examined rehabilitation after a derotation osteotomy, found that all children involved in the study eventually returned to at least their preoperative level of function, and indicated that function was not inhibited after recovery. Preoperatively, the study examined 71 children with Cerebral Palsy who underwent femoral derotation osteotomy between October 1990 and July 1998. Fifty-nine of them had bilateral osteotomies, while the rest had only one hip operated on. The study examined four groups of children, non-ambulators, therapeutic walkers (non-functional



gait patterns), household walkers (walk independently in the house), and community walkers (complete ambulation). The authors of the study found that the degree of function prior to the operation had a large effect on the rehabilitation time, but that all rehabilitation was complete in less than two years. It was also found that children with household or community ambulation rehabilitate more quickly than non-ambulatory children. Furthermore, the authors found that the rehabilitation time overall averaged about nine months. Finally, patients who received any regular care from a licensed physical therapist in either an in-patient or out-patient setting showed a more rapid return to function; however, no mention was made in regard to the effect of a home therapy program (Stasikelis et al. 2003). Therefore, it seems that after the femoral derotation osteotomy, most patients are able to return to their original level of function, but the study did not indicate whether or not the hip remained in the reduced position, or if pain was decreased.

A similar study conducted by Hoffer et al. (1985), evaluated twenty children with spastic Cerebral Palsy who underwent femoral derotation osteotomy. The original indication for these particular surgeries was inadequate coverage of the femoral head (an acetabular problem that often leads to dislocation). These patients also experienced pain and dislocation of the hip and some underwent the surgery in order to improve or maintain walking ability. The ages ranged from four years to fifteen years. Each patient was followed for at least seven years after their operation. All patients were placed in hip spica casts after the surgery, until the bones fused. After bone fusion was complete, the casts were worn intermittently for two weeks to two months, during which the patient

underwent physical therapy to regain range of motion. Overall, healing was complete in about eight weeks (Hoffer et al. 1985).

At follow up, twenty out of the twenty five patients maintained a well centered hip, while four hips remained subluxated, but to a lesser degree than preoperatively. One hip was dislocated at follow-up. Furthermore, walking ability did not change dramatically. Twelve patients, who were not able to walk before surgery, remained non-ambulatory, while two patients who were only able to crawl prior to the surgery were able to walk at final follow up. One patient, age eighteen, who was able to walk around the house, was unable to walk after the surgery. However, three patients who were able to walk in the house prior to surgery were able to improve to become community walkers after the surgery. Finally, two patients who required braces to walk prior to the surgery were able to walk without braces postoperatively. Overall, walking ability improved in a majority of patients, but not dramatically.

The range of motion at the hips was also measured both preoperatively and postoperatively and it seems that range of motion remained unchanged with the exception of internal rotation, which averaged about 28 degrees (with knee extended) after surgery, indicating an improvement. Finally, pain was evaluated both before and after surgery, and of the six patients that experienced pain prior to surgery, three continued to have pain afterward. Two patients experienced persistent pain, despite having hips in the reduced and anatomically correct position, and one patient did not experience preoperative pain, but developed pain after the operation due to avascular necrosis, a complication that can result from the operation (Hoffer et al. 1985).

### Complications After Surgery:

While most patients return to their previous level of function and many improve after a femoral derotation osteotomy, many complications can result, especially in more involved cases. The most common complications include avascular necrosis and redislocation (Hoffer et al. 1985). Avascular necrosis is the loss of blood supply to the joint, and can be permanent. Other complications include considerable pain, premature closure of the physis of the femoral neck (causes femur to stop growing), coxa magna or the enlargement and deformation of the femoral head, and trochanteric bursitis (Root et al. 1995). Finally, fractures of the femur are also a complication of the procedure. Many of these complications can be predetermined by understanding the different risks involved with the procedure and understanding which patients may be at a greater risk.

A study completed by Stasikelis et al. (1999), evaluated seventy-nine children with Cerebral Palsy who underwent the derotation osteotomy for hip dislocation or subluxation in order to determine postoperative complications for the procedure. The authors found that twenty five percent of their patients had at least one complication, while sixteen patients sustained a total of twenty- five fractures. Of these sixteen patients, one experienced bilateral fractures, while another endured three fractures and a third sustained a total of six fractures. All but two of the fractures were experienced between one week and five months of the procedure. None of the fractures were associated with severe trauma. Five patients developed ulcers, which required an average of two weeks of local care. Finally, the authors found that three of their patients died; one at one- week post operative, one at two weeks and one at five months after surgery. Of the patients

with complications, 13 had gastrostomies or tracheotomies, while seven of the remaining sixty also endured complications. Finally, only one of the 13 ambulatory patients endured complications. Overall, they concluded that ambulatory patients as well as patients without gastrostomies or tracheotomies were at a lower risk for complications than those with such devices, while the non-ambulatory patient with a gastrostomy or tracheotomy is at the greatest risk.

Personal Experience:

I currently take care of a three-year-old girl named Danielle, who has Cerebral Palsy and microcephaly. In July of 2006 she underwent a derotation osteotomy. Prior to her surgery, her hip would consistently dislocate and caused her a lot of pain. While changing her diapers, I had to be careful not to cross her feet at the ankles because her left hip would easily dislocate. Although her left hip had a tendency to dislocate, she really enjoyed kicking her legs and laughing, while lying down. I did notice a tendency for her to kick her right leg more than her left. I rarely had her sit in my lap or in her “kid cart” (a modified stroller), because sitting made her uncomfortable and caused her a lot of pain.

After the surgery and during her recovery, Danielle experienced a lot of pain and discomfort; she could be hard to calm down sometimes, and pain management became her mother’s primary concern. After about six weeks in her spica cast, she spent another four weeks using the cast as a type of brace that could be taken on and off as tolerated. This period, during which she was in and out of the cast, was the most difficult because

she was still in some pain from the surgery and her muscles were sore and stiff due to six weeks in the spica cast.

However, after five months, I have noticed her behavior returning to normal. She laughs and kicks a lot more often while lying down, and tolerates sitting up much better. I can hold her in my lap or place her in the “kid cart” for an extended period of time and she remains content. From my experience and observations, she experienced no complications with the surgery and her hips appear to be symmetrical, although it is easier for her to extend and move her right leg. It has also become easier to change her diaper, although I still avoid crossing her legs as a precaution because she could still have a fracture. Although she still experiences some muscle spasms and pain in certain positions, overall she seems to tolerate many more activities and remains happier.

#### Conclusions:

Although I have had a positive experience taking care of a child who underwent a derotation osteotomy, the present research does not support the procedure. The research supports maintaining the hip in a reduced position, but does not offer a procedure with minimal risks of complications or higher levels of success.

In my research and experience, I have found that a femoral derotation osteotomy is an option for maintaining the hip in a reduced position; however, many factors must be taken into consideration including the type of Cerebral Palsy and how severe the condition is. The more severely the child is affected, the more risky the procedure will be, and feeding tubes and other health concerns elevate the risk of any surgery. Also, it is

important to consult multiple orthopedic surgeons to determine if the hip can be reduced. Many times, the structure of the hip and the musculature surrounding the hip does not allow the femoral head to be successfully placed back into the joint capsule. The acetabulum may not be deep enough or the muscles surrounding the hip may be too short and could re-dislocate the hip; causing further complications. Furthermore, it is necessary to evaluate the pain experienced by the child and to evaluate whether or not the child will most likely experience a decrease in pain. Finally, it must be determined whether or not the child will be able to walk with a hip that is in the reduced position. A reduced hip is necessary for ambulation and if a child has the potential to walk, the surgery may be worth the risks associated with it.

Further research is needed in many different areas to fully understand the causes of a chronically dislocated hip in Cerebral Palsy and the ensuing treatments possible. More research is needed to discover other ways to reduce the hip that are not as invasive as the femoral derotation osteotomy. Furthermore, research is needed to determine other soft-tissue operations that can be combined with the derotation osteotomy to increase the probability for success, such as muscle lengthening surgeries and acetabular reconstruction to avoid re-dislocation caused by short muscles. Many of these operations are already being performed, but it is necessary to do more research to determine the most beneficial combination and to develop alternative treatment strategies for the chronically dislocated hip in Cerebral Palsy.

## **Chapter 6: More than Medicine**

Raising a child with special needs such as Cerebral Palsy can prove to be demanding and challenging. As stated previously, many disabilities are associated with Cerebral Palsy and each must be cared for in a specific way. Indeed, we cannot simply analyze the effects of medical care as many other factors contribute to the quality of life of CP patients. More specifically, when treating children with developmental disorders such as Cerebral Palsy, practitioners must take into consideration the emotional factors involved in raising children with special needs.

### **Stress:**

Although response to special situations varies greatly among individuals, parents of children with special needs are at risk for emotional difficulties. Higher stress can result from the many demands placed on a family with special needs children. Many studies have been conducted in order to determine the amount and primary sources of stress placed on a family with special needs children. Dyson (1993) compared stress levels in families of children with special needs to the stress levels of families of typical children of similar ages. The study did find differences in stress related to specific factors such as the care of the child and pessimism over the child's future. Families of children with special needs showed a greater increase in stress dealing with these two factors over a shorter amount of time. The study also found that a child's disability consistently accounted for a large portion of the parent's stress. Beyond the disability, stress was also caused by the family relationship (Dyson 1993). While it seems that there

was no significant change over time in the levels of stress experienced by parents of children with special needs and parents of typical children, the overall level of stress was greater in parents of children with special needs (Dyson 1993). Overall it seems that parents of children with special needs experience a higher level of stress than parents of typical children, but this stress level does not increase or decrease over time.

#### Factors Contributing to Stress:

Many factors can contribute to the stress experienced by parents of children with developmental disabilities; however, not all of them are equally relevant. These factors may include the extent of the child's physical disease or disability, the strain of caring for a child in daily living activities, as well as psychosocial stress (Horton and Wallander 2001). Both family functioning and the severity of the child's disability are related to the overall stress experienced by the family. Many other variables may also affect family functioning and can be used to predict the level of stress experienced by the family. These variables include family resources and perceived family support, of which family resources are a better predictor of overall stress.

It also seems that the severity of the child's disability has very little influence on the level of stress experienced by the parents, but it does have a significant impact on the relationship between the child and the parent. Finally, the child's social skills tend to have a stronger impact on parent stress than other abilities such as motor, communicative, adaptive behavior or cognitive abilities (Smith et al. 2001). Overall, many variables contribute to the stress levels experienced by parents of children with developmental



disabilities, therefore, the stress level should be taken into consideration when developing a treatment plan.

#### Coping Strategies and Decreasing Stress Levels:

Even though many factors contribute to the stress levels of parents raising children with special needs, many other factors may also lower this stress. Horton and Wallander (2001) analyzed the effects of hope and social support on the level of stress experienced by parents of children with special needs. They compared the levels of distress among mothers raising children with Cerebral Palsy, spina bifida or insulin-dependent diabetes mellitus and found that there was no overall difference in the levels of stress experienced by each mother. Furthermore, there was a negative correlation between stress and both hope and perceived social support. In conclusion, this study showed that the level of perceived support as well as the level of hope that each mother experienced contributes to a lower stress level.

The relationship between stress level and hope as well as perceived social support is maintained throughout various levels of severity of the Cerebral Palsy. It would seem that the more severely affected the child with Cerebral Palsy is, the higher the level of parental stress. However, this is not the case. Rather, it is the mother's perception of her situation and the strains placed on her resources that are associated with her ability to cope and her level of experience stress, rather than her child's disability. Overall, it seemed that the higher the level of hope reported by mothers, the lower their stress level. This was amplified when the mother also perceived a higher level of social support.

Social support has been found to have a positive impact on the ability of a mother to cope. A mother's perception of the number of people available to her, as well as her satisfaction with this support, were found to lower her stress levels (Horton and Wallander 2001).

Another study conducted by Raina et al. (2005) showed that the level of social support was helpful in reducing stress levels among caregivers (primarily mothers) of children with Cerebral Palsy, but also found that finding ways to effectively control a child's behavior had a greater effect. The study found that child behavior problems are the single most important child characteristic that predicts caregiver psychological well-being. While perceived social support was important in lowering stress levels of caregivers, it is second to the ability of the immediate family to work together, and both factors followed maintaining positive child behavior. Considering the importance of behavior management, the authors advise health care providers to provide the parents with effective cognitive and behavioral strategies to manage their child's behavior. Furthermore, it is important to provide interventions that support the nurturing of the family as a whole and to value family functioning as much as the development of the child with special needs (Raina et al. 2005). Many organizations are available to help with coping strategies and can offer advice on raising a child with Cerebral Palsy (Table 2).

Table 2: Support Groups

<b>Support Group</b>	<b>Website</b>
Family Village	<a href="http://www.familyvillage.wisc.edu">www.familyvillage.wisc.edu</a>
Parent to Parent	<a href="http://www.p2pusa.org/">http://www.p2pusa.org/</a>
Exceptional Parent	<a href="http://www.eparent.com/">http://www.eparent.com/</a>
CP Parent Resource Center	<a href="http://www.cpparent.org/">http://www.cpparent.org/</a>

Retrieved May 1, 2007, from 4 My Child: Help and Hope for Life Web site: [www.4mychild.com](http://www.4mychild.com)

Overall, it seems that managing the behavior of the child as well as the quality of social support and high levels of hope can help to lower the stress experienced by mothers of children with special needs. Other studies are needed to evaluate the effect of the same factors on stress in fathers of children with special needs. Many studies show the role of the father to be supportive of the mother, who takes on the major burden of raising the child (Hirose and Ueda 1990).

#### The Role of the Father:

Fathers tend to react much differently than mothers to having a child with special needs. Fathers tend to respond less emotionally and focus on possible long-term concerns, while mothers tend to respond more emotionally and have a greater concern for the immediate care of their newborn. Fathers may also report fewer symptoms of distress, higher self esteem and a greater sense of control than mothers of children with special needs. However, fathers may also have a tendency to deny and suppress uncomfortable emotions and this denial may cause a father to withdraw. If the father does become distant from his family or leaves, a great stress is placed on the family as a whole. In

general, though, most fathers adapt well to having a child with special needs. It is important for health care professionals to recognize the father's potential role in caring for the child and to include him in the treatment plan as well as regular meetings to update him on the progress and health of his child (Seligman and Darling 1997).

In my experiences at Adam's Camp ([www.adamscamp.org](http://www.adamscamp.org)), I have seen how social support and perceived hope can decrease the amount of stress experienced by the parents. Adam's Camp is a therapy and summer adventure camp for children of ages ranging from 4-25 years. The camp provides five- eight hour days of therapy from all disciplines (occupational, speech, physical, art, music and behavior), to children with all types of special needs. The camp also provides summer camp activities and overnight camping experiences to older and higher functioning children.

The camp has also developed support groups for parents and a sibling program for the brothers and sisters of the campers. In these groups, parents and siblings are able to talk openly about their experiences and are able to understand each other, because many of them experience similar challenges. At camp, both parents and siblings are able to find the support systems that they may not have had in the past. Having a social support system and the opportunity to share with other families that are experiencing the same challenges can be extremely beneficial. I have talked to many parents, who express that parents of typical children just aren't able to understand their situation like the other parents at camp. They have expressed their relief at finding a community that they can belong to and a support system that they can rely on. They have also expressed the hope that they have found at camp. At the beginning of the week, each set of parents meets

with the therapy team to discuss their wishes for the child and goals that they would like to see their child reach. The therapy team then helps the family narrow down their wishes into a few obtainable goals that they will work on throughout the week. More often than not, the child reaches at least one of these goals and usually excels far past them.

Observing their child reach new goals provides more hope for future progress and often lowers the level of stress experienced by the parents.

### Financial Strategies

The cost of raising a child with Cerebral Palsy varies greatly from individual to individual, and can usually be estimated by a the treatment team. The cost of medical bills, therapy, adaptive equipment, among many other things, can be high and can place a great burden on the family. It is important to begin the process of finding financial help as soon as the diagnosis is given (Thompson 2000). The first step is to seek information on any financial assistance programs, which are usually provided by the state. If state agencies are contacted immediately, then it is often easier to get financial assistance. Some state resources available are the Public Health Department and state agencies related to the child's disability. For Cerebral Palsy, the state agency is the United Cerebral Palsy Association (Table 2). It can be extremely difficult to find financial assistance, but with enough persistence and dedication, it can be accomplished (Thompson 2000).

Table 3: Resources for Funding

<b>Organization</b>	<b>Website</b>
Lions Club	<a href="http://www.lionsclubs.org">www.lionsclubs.org</a>
Special Kids Fund	<a href="http://www.specialkidsfund.org">www.specialkidsfund.org</a>
Disabled Children's Relief Fund	<a href="http://www.dcrf.com">www.dcrf.com</a>
Easter Seals	<a href="http://www.easterseals.com">www.easterseals.com</a>

Retrieved May 1, 2007, from 4 My Child: Help and Hope for Life Web site: [www.4mychild.com](http://www.4mychild.com)

#### Conclusion:

In summary, Cerebral Palsy is an umbrella term that is used to describe a wide range of conditions that are caused by brain damage during fetal development, during birth or right after birth. CP is the most common cause of severe physical disability in childhood and occurs in about one to five of every 1000 births in Western countries. The most common physical symptoms of CP include spasticity and contracture of muscles. This tightening of the muscles often causes deformities in bones that inhibit multiple levels of function.

More specifically, spasticity or contracture of the muscles surrounding the hip can cause the femoral head to be pulled out of the acetabulum, which leads to subluxation and dislocation. Hip dislocation is a common problem in CP and it is estimated that 7% of ambulatory patients and 60% of patients with quadriplegia experience dislocation. Dislocation can have long term implications if it goes untreated, including constant pain, difficulty in sitting, standing and walking as well as limits in perineal care. There are

many treatments for dislocation, the most common of which is the femoral derotation osteotomy.

The femoral derotation osteotomy is a hard bone surgical procedure in which the surgeon makes a cut on the femur perpendicular to the femoral shaft and then repositions the femur in the acetabulum. While this procedure can be successful, most of the research points to painful complications including fractures, redislocation, and avascular necrosis. Research also indicates that the goals of the procedure are not always accomplished and further research is needed to determine other treatments for dislocation that provide better results and that reduce pain and recovery time. Also, research is needed to determine other procedures that may be paired with the derotation osteotomy, such as soft-tissue procedures, that can enhance the effectiveness of the treatment. Overall, it seems that the derotation osteotomy is not the best treatment for hip dislocation and cerebral palsy, but for now, it is the only treatment that remains.

### Works Cited

- 4 My Child: Help and Hope for Life Web site: [www.4mychild.com](http://www.4mychild.com). Retrieved May 1, 2007
- Acetabular Angle . Retrieved April 19, 2007, from Acetabular Angle Web site:  
<http://bmc.ub.uni-potsdam.de/1471-2431-5-17/F2.htm>
- Bear, Connors and Paradiso. 2001. Neuroscience: Exploring the Brain.2<sup>nd</sup> Ed. Baltimore. Lippincott Williams & Wilkins.
- Berkow, Robert. 1997. Merck Manual of Medical Information. New York, New York. Pocket Books.
- "Cerebral Palsy." Disabled Village Children . 1987. Disabled Village Children . 26 Feb 2007
- Chene Paul D., and Palmer, Frederic B. 1997. Overview: Cerebral Palsy. Mental Retardation and Developmental Disabilities Research Reviews. 3:109-111.
- Comparison of Varus and Valgus Deformity . Retrieved April 19, 2007, from Merck Medicus Web Site  
<http://www.merckmedicus.com/ppdocs/us/hcp/diseasemodules/osteoarthritis/figures/figure19.html>)
- Dabney, Kirk W., Lipton, Glenn E., Miller, Freeman. 1997. Current Opinion in Pediatrics. 9:81- 88.
- DeLuca, Peter A 1996. The Musculoskeletal Management of Children With Cerebral Palsy. IN: England, Stephen, editor. The Pediatric Clinics of North America, Common Orthopedic Problems II. Philadelphia :W.B Saunders Company. P. 1135-44.
- Divisions of the Nervous System . Retrieved April 19, 2007, from Think Quest Web site:  
<http://library.thinkquest.org/28807/data/nervous2.htm>)
- Dyson, Lily L. (1993). Response to the Presence of a Child With Disabilities: Parental Stress and Family Functioning Over Time. American Journal on Mental Retardation. 98(2): 207-218.
- Eicher, P.S., Batshaw, M.L., 1993. Cerebral Palsy. Pediatric Clin. North America. (Serial Online) 40(3):537-51. Available from PubMed: Accessed November 29, 2006.



- Fagerston, Timothy L (ed.). (1998) *The Hip Handbook*. Boston: Butterworth-Heinemann.
- Glessner, James R 1969.. Derotation Osteotomy of the Femur in Cerebral Palsy. *Henry Ford Hospital Medical journal*. 17(1): 59-62
- Feldman, D (12/28/2006). Dr. Feldman . Retrieved May 1, 2007, from Pediatric Orthopedics.com Web site: [http://www.pediatric-orthopedics.com/Treatments/Hips/Dr\\_\\_Feldman/dr\\_\\_feldman.html](http://www.pediatric-orthopedics.com/Treatments/Hips/Dr__Feldman/dr__feldman.html)
- Folkerth, Rebecca D. 2005. Neuropathologic Substrate of Cerebral Palsy. *Journal of Child Neurology*. 20(12):940-949.
- Giuseppe, Selva, Miller, Freeman, Dabney, Kirk W. 1998. Anterior Hip Dislocation in Children with Cerebral Palsy. *Journal of Pediatric Orthopaedics*. (Serial online) 18(1): 54-61. Available from Ovid. Accessed March 4, 2006.
- Glessner, James R. 1969. Derotation Osteotomy of the Femur in Cerebral Palsy. *Henry Ford Hospital Medical Journal*. 17(1) 59-62.
- Gormley, Mark E. 2001. Treatment of neuromuscular and musculoskeletal problems in cerebral palsy. *Pediatric Rehabilitation*. 4(1): 5-16.
- Hagglund, G., Andersson, S., Duppe, H., Lauge-Pedersen, H., Nordmark, E., Westborm, L. 2005. Prevention of dislocation of the hip in children with cerebral palsy. *M. Journal of Bone and Joint Surgery*. (Serial online). 87(1):95-101  
N. Available from PubMed. Accessed March 6, 2006
- Hayong, Kim., Aiona, Michael, Suessman, Michael. 2005. Recurrence After Femoral Derotational Osteotomy in Cerebral Palsy. *Journal of Pediatric Orthopedics*. 25(6):739-743.
- H. Eigsti, public presentation, 11/30/2006
- Heimer, Lennart. 1995. *The Human Brain and Spinal Cord: Functional Neuroanatomy and Dissection Guide*. Second Ed. New York: Springer-Verlag.
- Hirose, Taiko and Ueda, Reiko. 1990. Long-term follow-up study of cerebral palsy children and coping behavior of parents. *Journal of Advanced Nursing*. 15:762-770
- Hoffer, MM., Stein, GA., Koffman, M., and M. Prietto. 1985. Femoral varus-derotation osteotomy in spastic cerebral palsy. *Journal of Bone and Joint Surgery*. 67(8): 1229-1235.

- Horton, Trudi Venters and Jan L. Wallander. 2001. Hope and Social Support as Resilience Factors Against Psychological Distress of Mothers Who Care for Children with Chronic Physical Conditions. *Rehabilitation Psychology*. 46(4): 382-399.
- Johnsen, Stanley D., Bodensteiner, John B., Lotze, Timothy E. 2005. Frequency and Nature of Cerebellar Injury in the Extremely Premature Survivor with Cerebral Palsy. *Journal of Child Neurology*. 20(1):60-64
- Johnston, Michael V. and Hoon, Alexander H. 2006. Cerebral Palsy. *Neuromolecular medicine*. 8:435-452
- Kasser, JR., Bowen, JR., and GD MacEwen. 1985. Varus derotation osteotomy in the treatment of persistent dysplasia in Congenital dislocation of the hip. *Journal of Bone and Joint Surgery*. 67(2): 195-202.
- Koman, L. Andrew, Paterson Smith, Beth, Shilt, Jeffrey S. 2004. Cerebral Palsy. *The Lancet*. 363:1619-31.
- Marieb, Elaine N. 2004. *Human Anatomy and Physiology* 6<sup>th</sup> Ed. San Francisco: Pearson Education Inc.
- McClure, Shannon. 2005. Hip dislocation in cerebral palsy. *Current Opinion in Orthopedics*. (Serial Online) 16(6): 478-483. Available from Ovid. Accessed March 4, 2006.
- Merriam-Webster's Medical Dictionary (1995). Springfield: Merriam-Webster, Incorporated.
- Miller, Freeman, Bachrach, Steven J. 1995. *Cerebral Palsy: A Complete Guide to Care Giving*. Baltimore. The Johns Hopkins University Press.
- Msall, Michael E. 2006. Complexity of the Cerebral Palsy Syndromes: Toward a Developmental Neuroscience Approach. *Journal of the American Medical Association*. 296(13).
- National Institute of Neurological Disorders and Stroke. National Institutes of Health. 2006. *Cerebral Palsy: Hope Through Research*. Bethesda, MD.
- Nolte, John. 1999. *The Human Brain: An Introduction to Its Functional Anatomy*. Fourth Ed. St. Louis: Mosby Inc.
- ohsu.edu . Retrieved April 19, 2007, from Center Edge Angle Web site:  
<http://www.ohsu.edu/radiology/teach/kojima/hip.htm>

- Raina Parminder, O'Donnel Maureen, Rosenbaum Peter, Brehaut Jamie, Walter Stephen D., Russle Dianne, Swinton Marilyn, Zhu Bin, and Ellen Wood. (2005) The Health and Well- Being of Caregivers of Children With Cerebral Palsy. *Pediatrics*. 115(6): 626-636
- Reddibough, DS., King, JA., Coleman, GJ., Fosang, A., McCoy, AT., Thomason, P., Grahm, HK. 2002. Functional outcome of botulinum toxin A injections to the lower limbs in cerebral palsy. *Dev. Med. Child Neurol (Serial Online)*. 44(12):820-827. Available from PubMed. Accessed December 2, 2006.
- Root, L., Laplaza, FJ., Brouman, SN., and DH Angel. 1995. The severely unstable hip in cerebral palsy. Treatment with open reduction, pelvic osteotomy and femoral osteotomy with shortening. *Journal of Bone and Joint Surgery*. 77(5): 703-712.
- Scrutton, David and Baird, Gillian. 1997. Surveillance measures of the hips of children with bilateral cerebral palsy. *Archives of Disease in Childhood*. 76:381-384.
- Seligman, Milton and Darling, Rosalyn Benjamin. (1997). *Ordinary Families, Special Children: A Systems Approach to Childhood Disability*. (Second Edition). New York: Guilford Press.
- Smith, Laura K., Weiss, Elizabeth Lawrence., and L. Don Lehmkuhl. 1996 *Brunnstrom's Clinical Kinesiology*. (Fifth Edition). Philadelphia: F.A. Davis Company.
- Smith, Timothy B., Oliver, Matthew N.I., Innocenti, Mark S. 2001. Parenting Stress in Families of Children with Disabilities. *American Journal of Orthopsychiatry*. 71(2): 257-261
- Soo, Brendan, Howard, Jason J., Boyd, Roslyn N., Reid, Susan M., Lanigan, Anna, Reddihough, Dinah, Graham, H. Kerr. 2006. Hip Displacement in Cerebral Palsy. *Journal of Bone and Joint Surgery*. 88-A(1): 121-129
- Stasikelis, Peter J., Davids, Jon R., Johnson, Beverly H., and Jeannine M. Jacobs. 2003. Rehabilitation after femoral osteotomy in cerebral palsy. *Journal of Pediatric Orthopaedics*. 12(5): 311-314.
- Svenningsen, Svein., Apalset, Kristen. Terjesen, Terje., Anda, Svein., 1989. Osteotomy for femoral anteversion: Complications in 95 Children. *Acta Orthopaedica Scandinavica*. 60(4): 401-405.
- The Handbook of Disabilities Retrieved May 1, 2007, from Cerebral Palsy Web site: <http://www.rcep7.org/projects/handbook/handbook.html>

Thompson, Charlotte E. *Raising a Handicapped Child*. (Revised and Expanded Edition). Oxford:Oxford University Press.

Thorogood, Christine., Alexander, Michael A. Cerebral Palsy. July 15, 2005.  
<<http://www.emedicine.com/pmr/topic24.htm>.>

Vinning, Eileen., Accardo, Pasquale J., Rubenstein, James E., Farrell, Susan E., Roizen, Nancy J. 1976. Cerebral Palsy: A Pediatric Developmentalist's Overview. American Journal of Childhood Disabilities. 130: 643-649.

What does the Cerebellar Vermis Look Like? . Retrieved April 19, 2007, from Medfriendly.com Web site: <http://www.medfriendly.com/cerebellarvermis.html>)

What is a Spica Cast? . Retrieved March 5, 2007, from SpicaCast.com Web site: <http://www.spicacast.com/>

"What is Cerebral Palsy ." Ontario Federation for Cerebral Palsy . 26 Feb 2007. Ontario Federation for Cerebral Palsy . 26 Feb 2007  
<<http://www.ofcp.on.ca/aboutcp.html##T>>.

Wilkinson, Andrew J., Natrass, Gary R., Graham, H. Karr. 2001. Modified Technique for Varus Derotation Osteotomy of the Proximal Femur In Children. ANZ Journal of Surgery. 71: 655-658.

Yokochi, Kenji. 2003. Clinical profiles of children with cerebral palsy having lesions of the thalamus, putamen and/or peri-Rolandic area. Brain and Development. 26(2004):227-232