

## Ocular anomalies in static encephalopathy: A review

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**S**tatic encephalopathy (SE) is defined as non-progressive dysfunction of the brain<sup>1</sup>. The effects on development depend on the part of the brain involved and on the severity of the damage<sup>2</sup>. Brain damage associated with SE is permanent; consequently, there is no cure.<sup>3</sup> **Cerebral palsies** are a subgroup of SE, defined as 'A group of disorders of the development of movement and posture causing activity limitation, that are attributed to non-progressive disturbances in the developing fetal or infant brain'<sup>4</sup>.

Where only one or a few specific relatively mild cognitive modalities are impaired, comprises the **learning disabled**, whereas more severe conditions affecting many or all cognitive domains comprise the **intellectually disabled**.<sup>5</sup> The degree of deficits in individuals with SE or the large subgroup CP is dependent on the location and extent of underlying CNS injury<sup>5</sup>. The clinical pattern is often predictive of the site of lesions and may be predictive of underlying cause<sup>5</sup>. Postnatal neural development may impart a pseudoprogressive appearance to the static deficits of CP, or of conditions within the wider spectrum of SE, due to the fact that damage to various systems may not become fully apparent until such systems "come on line" during postnatal development<sup>6</sup>. It is important to note that despite the possible infantile worsening of manifestations, most children with CP will experience, at varied rates and degrees, improvement over the course of their development<sup>5,6</sup>.

### Cerebral Palsy:

CP comprises the major subgroup of static encephalopathy, covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development and consists of group of conditions of different etiologies, but with distinctive clinical features<sup>7</sup>. The motor abnormalities dominate the clinical picture. The motor

disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, epilepsy, and secondary musculoskeletal problems<sup>8,9,10</sup>.

### Prevalence of CP:

In developed countries, the overall estimated prevalence of CP is 2-2.5 cases per 1000 live births<sup>11,12</sup>. The prevalence of this disorder among preterm and very preterm infants is substantially higher than term babies<sup>13,14</sup>. In the developing world, the prevalence of CP is not well established but estimates are 1.5-5.6 cases per 1000 live births<sup>13,14</sup>.

### Etiology and Risk factors:

The etiology of CP is very diverse and multifactorial. The causes are congenital, genetic, inflammatory, infectious, anoxic, traumatic and metabolic<sup>15</sup>. The injury to the developing brain may be prenatal, natal or postnatal<sup>16</sup>. The most important risk factor seems to be prematurity and low birth weight (LBW) with risk of CP increasing with decreasing gestational age and birth weight. CP is seen in 10-18% of babies in 500–999 grams birth weight<sup>17</sup>. CP occurs more commonly in children who are born very prematurely or at term. Although term infants are at relatively low absolute risk, term births constitute the large majority of all births, as well as approximately half of all births of children with CP.<sup>18</sup> Another risk factor is prenatal maternal chorio-amnionitis accounting for as much as 12% of CP in term infants and 28% in premature infants<sup>18,19</sup>. Cystic periventricular leukomalacia (CPVL) is a risk factor with 60%-100% of patients with CPVL developing CP. Perinatal cerebral hypoxia–ischemia remains a frequent cause of the chronic handicapping conditions of CP, mental retardation (MR), learning disability, and epilepsy<sup>20</sup>. Estimates suggest that between 2 and 4/1000 full-term newborn infants suffer asphyxia at or shortly before birth<sup>21</sup>.

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Approximately 15% to 20% of such asphyxiated infants who exhibit hypoxic–ischemic encephalopathy actually die during the newborn period, and of the survivors, 25% will exhibit permanent neuropsychologic deficits including MR, visual motor or visual perceptive dysfunction, increased hyperactivity, CP, and epilepsy<sup>20,21</sup>.

CP can be classified according to topographical distribution of motor involvement—monoplegia, hemiplegia, diplegia and quadriplegia and on the basis of neuro-muscular deficit into spastic (most common-70-75%), Dyskinetic (Dystonic + Choreoathetoid) (10-15%), Ataxic (<5%), Hypotonic (2.6%), Mixed (Spastic with any other form of CP) (15.4%)<sup>21</sup> Assessment of functional disability is done by Gross Motor Function Classification System (GMFCS) which classifies age-specific gross motor activity and Manual Ability Classification System (MACS) which classifies child's manual abilities with both hands according to severity to

provide an objective classification of the patterns of motor disability observed in patients with CP<sup>22,23</sup>.

#### Deficits seen in CP:

75% patients with CP present with associated deficits. These include<sup>21-27</sup>:

1. Mental retardation (MR) is a common association of CP up to an extent of 60%<sup>24</sup>.
2. Visual impairments and disorders of ocular motility are common (28%) in children with CP<sup>21</sup>.
3. There is an increased presence of strabismus, amblyopia, nystagmus, optic atrophy, and refractive errors. Children whose CP is due to PVL are also more likely to have visual perceptual problems like weakness in visual object recognition, visuospatial skills, visual memory and oculomotor control<sup>25, 26</sup>.

**Table-1: Overall visual problem in children with CP in percentages:** <sup>30-40</sup>

Research	No of participants with CP	Visual impairment (%)	Specific visual problem observed
Breakey <sup>30</sup> (1955)	100	56	Squint (49%)
Altman et al <sup>31</sup> . (1966)	64	92	Refractive errors (90%) Squint (66%)
Black <sup>32</sup> (1982)	117	77.8	Squint (52.5%)Refractive errors (50%)
Schenk-Rootlieb et al <sup>33</sup> . (1992)	164	71	Cerebral visual impairment (84%)
Arnoldi et al <sup>34</sup> . (2006)	131	46	Refractive errors (37%)Amblyopia (24%)Optic nerve abnormality (16%)Cortical visual impairment (14%)
Katoch et al <sup>35</sup> . (2007)	200	68	Refractive errors (33.5%)Squint (39%)
Venkateswaran & Shevell <sup>36</sup> (2008)	92	80	Not specified
Hou et al <sup>37</sup> . (2010)	354	38.98	Not specified
Elmenshawy et al <sup>38</sup> . (2010)	46	76	Refractive errors (67.2%)Squint (32.8%)Cerebral visual impairment (51.4%)
Sasmal et al <sup>39</sup> (2011)	140	42.1	Squint (36.4%)
Ozturk et al <sup>40</sup> (2012)	194	78.9	Squint (55.2%)

4. Hearing impairment occurs in approximately 12% of children with CP. This occurs more commonly if the etiology of CP is related to very LBW, kernicterus, neonatal meningitis or severe hypoxic-ischemic insults<sup>21</sup>.
5. Epilepsy is common in children with CP, 35% to 62% of children develop epilepsy.
6. Speech and language is affected in CP due to bilateral corticobulbar and oro-motor dysfunctions<sup>21, 24</sup>.
7. Oro-motor problems with feeding difficulties, swallowing dysfunction and drooling are also present<sup>27</sup>.
8. Abnormalities of proprioception and tactile sensations are common in children with CP<sup>21</sup>.
9. Psychiatric disorders such as anxiety, depression, conduct disorders and hyperkinesia and inattention are seen as often as in 61% of 6%-10 year-old-children with hemiplegic CP<sup>21, 27</sup>.

Ocular disorders are very common in children with CP. Guzzetta et al (2001) hypothesized that disorders of visual function are most often due to damage of the central visual pathway<sup>28</sup>. Hoyt et al (2003) hypothesized that perinatal hypoxic ischemia is the most cause of visually significant brain injury in CP and damage to any one or more of at least 5 separate visual systems (primary visual cortex, visual associative cortex area, optic radiations, optic nerves, and visual attention pathways) may account for the visual disability of children with brain injury<sup>29</sup>.

#### A. Strabismus and ocular motility disturbances

Ocular motility disturbances and strabismus has been found to have the highest incidence amongst ocular disorders in most studies. The incidence of strabismus within the general population is considered to be 2.5–4%<sup>41</sup>.

The incidence in CP has been variously reported as 75% by Guibor<sup>42</sup> (1953), 37% by Douglas<sup>43</sup> (1960,61), 31% by Evans<sup>44</sup> (1968), 25% by Asher et al<sup>45</sup> (1950), 48% by Breakey<sup>30</sup> (1955), 43% by Schachat<sup>46</sup> (1957) and 35.7% by Govind et al<sup>47</sup> (1988).

#### Various studies have reported types of strabismus in CP:

Guibor<sup>42</sup> postulated that the ocular motility defects occur due to the cortical disturbances present in these patients. Guibor (1950) reported ocular defects in more than 50% of 142 children with CP in their study. Esotropia was

observed most frequently, in 51% cases as against exotropia in 9% cases. Horizontal conjugate defects were observed in 33% patients<sup>42</sup>. Schrire et al (1956) have found strabismus in 16 out of 73 cases. Breakey et al (1955)<sup>30</sup> also reported a high prevalence of strabismus (49/100) in a set of 100 patients with CP. Schachat et al (1956)<sup>46</sup> found ocular motility problems in 46/98 children. 43 patients had squint, of which 22 had convergent and 21 had divergent squint<sup>48</sup>.

Smith (1965) noted the ratio of convergent to divergent squint was 2.5:1 and the ratio of noncomitant to comitant squint was also 2.5:1<sup>49</sup>. Govind et al (1988) reported strabismus in 35.7% with 20% (comitant) and 17.5% (paralytic)<sup>47</sup>. Black et al (1982) studied the convergence: divergence ratio in 120 children with CP and observed it to be about 2-3:1 among subjects with concomitant squints as against about 8-10:1 in subjects with strabismus without CP. 10 There were 18 children with incomitant squints, of which 2 had Duane's retraction syndrome (DRS)<sup>32</sup>.

Erkkila et al (1996) analyzed the characteristics of squint and amblyopia in 48 children of CP with strabismus. Congenital esotropia was common and ratio of primary convergent versus divergent strabismus was 1.9:1. 17% cases of strabismus were of paralytic origin, 52% patients had vertical deviations and nystagmus was noted in 16% patients<sup>50</sup>.

Ghasia et al (2008) studied different degrees and types of visual dysfunction in 50 children with different severity of CP, using both, the topographical and the GMFCS system. Horizontal strabismus prevalence was high in each level of GMFCS, with primary esotropia exceeding exotropia by a ratio of 2.2:1. Prevalence of primary comitant esotropia ranged from 60% to 70% in levels I and II (mildly impaired group) and 40% in levels IV and V (severely impaired group)<sup>51</sup>.

Ozturk et al (2012) found diplegics (47.4%) and tetraplegics (36.1%) were found to harbor a greater extent of abnormal ocular findings than hemiplegia (16.5%). The group with tetraplegia had the greatest extent of visual problems. Strabismus was seen in 107 patients (55.2%)<sup>40</sup>. The ratio of esotropia to exotropia was 2.5:1. Of 73 patients with esotropia, 31 (42.5%) had refractive accommodative esotropia, while 11 cases (15.1%) had variable angle esotropia<sup>40</sup>. Variable angle exotropia was also seen in 6 of 31 patients with exotropia. Vertical deviation was seen in 5 cases. Variable angle means angle is not constant. Isolated vertical deviation was seen<sup>40</sup>. Lew et al (2014)<sup>52</sup>

studied 47 children of CP. 21 (44.7%) children had strabismus. Esotropia was present in 12 (25.5%) cases, exotropia in 8 (17.0%) cases and hypertropia in 1 (2.1%) case<sup>52</sup>.

### B. Refractive errors

A positive correlation between the extent of brain damage and refractive errors, particularly high hypermetropia, has been noted by Jevon and Gardiner<sup>53,54</sup>. Jevon (1967) hypothesized that hypermetropia is more common than myopia amongst educationally subnormal children<sup>53</sup>. Gardiner (1963) hypothesized incidence of hypermetropia amongst brain-damaged children at school for the physically handicapped<sup>54</sup>.

Govind et al studied the distribution of refractive status in 70 patients with CP. 20 (28.5%) of the total cases had refractive errors, which included 50% (10) cases with astigmatism, 25% (5) with myopia and 25% (5) with hypermetropia<sup>47</sup>. Ghasia et al studied 50 children where all had low-to-moderate degrees of ametropia (-0.50 D to -4 D), with hyperopes exceeding myopes by a ratio of 2.5:1<sup>51</sup>. The most common type of ametropia was low to moderate hyperopia. A trend was evident toward high myopia in the children with severe CP (levels 3–5)<sup>51</sup>. Anisometropia was detected in 10% to 20%, distributed equivocally across all levels of GMFCS<sup>51</sup>. With respect to anatomic subtype and sensory deficits, children with diplegic CP were distinguished by a substantially higher percentage (69%) of low to moderate hyperopia<sup>51</sup>. A higher percentage (59%) of children with spastic CP had low to moderate hyperopia, whereas a higher percentage (44%) of mixed CP had high myopia<sup>51</sup>.

Lew et al (2014) studied 47 children of CP of which 37 had ametropia including myopia (23.4%), hyperopia (46.8%), and astigmatism (34%). They found that hyperopia was higher in the higher levels of GMFCS<sup>52</sup>. When the distribution of ametropia across the GMFCS levels were assessed, the prevalence of ametropia was observed to be higher in the severely impaired group (level IV and V) as compared with the mildly impaired group (Level I-III)<sup>52</sup>.

### C. Amblyopia

Amblyopia is an important cause of subnormal vision in children with CP as described by Guibor<sup>42</sup>. Guibor et al (1953) had commented that amblyopia may result from the failure of development of vision or from deterioration of vision as a result of disuse or mal-use<sup>42</sup>. Schrire et

al (1956) observed amblyopia in 12 out of a study group of 73, associated with strabismus and anisometropia<sup>48</sup>. Black et al (1982) found an incidence of 15% amblyopia co-existing with strabismus, anisometropia or both in children with CP<sup>32</sup>.

### D. Gaze disorders:

Black et al (1982) found that nystagmus was found only in the ataxic and spastic types of CP<sup>32</sup>. Jerky eye movements, not amounting to true nystagmus, were seen in 3 children with spasticity<sup>32</sup>. 8 of the 19 children had searching or pendular nystagmus associated with obvious ocular lesions, with a very marked latent nystagmus superimposed in 4 patients. 3 other children with pure latent nystagmus were observed, associated in each case with a convergent squint. Of those patients with central nystagmus, 3 had upbeat nystagmus and 5 had horizontal nystagmus. All of the former and 1 of the latter had pure ataxic CP. Gaze palsies were seen in 5 patients<sup>32</sup>. Katoch et al<sup>35</sup> and Govind et al<sup>47</sup> reported nystagmus in 5.5% (11 out of 200) and 5.7% (4 out of 70) patients respectively<sup>35,47</sup>. Lew et al (2015)<sup>52</sup> reported infantile nystagmus in 2 patients diagnosed with bilateral spastic CP. One child with bilateral spastic CP had left-gaze palsy in both eyes<sup>52</sup>.

### E. Visual field defects:

The presence of field defects in children having CP was noticed first by Schrire in 1953 where he found Homonymous hemianopia in 1 out of 73 of his cases<sup>48</sup>. Black et al (1982) found 11% incidence (13 children) of visual field defects<sup>32</sup>. They were found only in children with spastic CP. Hemianopia was present in children with Spastic diplegia (2), spastic quadriplegia (3), spastic hemiplegia (1) and constriction of fields in spastic diplegics (3) and spastic quadriplegics (4)<sup>32</sup>.

### F. Cerebral Visual Impairment (CVI)<sup>55</sup>

Schenk-Rootlieb et al (1992)<sup>33</sup> reported an incidence of 84%. Cerebral visual problems are frequent among children affected by periventricular leukomalacia (PVL)<sup>55</sup>.

### G. Delayed visual maturation (DVM)

Delayed visual maturation (DVM) is a term used to describe infants who do not exhibit the ability to fix or follow objects in the environment, but subsequently improves by the age of 6 months without treatment<sup>56</sup>. *CP and MR were found much more commonly in preterm infants with DVM than in preterm infants without DVM<sup>56</sup>.*

## H. Other eye defects:

Guibor (1953) reported an incidence of 2% optic atrophy, 0.5% macular coloboma and 2% ptosis in the cohort with CP<sup>42</sup>. Schrire(1956) reported optic atrophy in 4.1% and anisocoria in 1.56%<sup>48</sup>. Breaker(1955) reported association of congenital cataract with iris coloboma in his group of patients. These defects were found in approximately 25% cases<sup>30</sup>. Schacat(1956) et al evaluated 98 patients, out of which he reported 1 case of ptosis, 1 of congenital cataract, 1 of corneal leucoma<sup>46</sup>. Diamond et al(1959) in their study on 17 cases of CP have reported congenital myopia (1), alternating hyperphoria (1), congenital corneal scar (1) and congenital word aphasia (2) in CP patients<sup>57</sup>. Black et al (1982) in their study on 180 children reported microphthalmos (5 cases), buphthalmos (1 case), corneal opacity (2 cases), cataract (3 cases), heterochromia iridis (3 cases), uveal coloboma (3 cases), pigmentary retinopathy (3 cases), retinopathy of prematurity (3 cases), optic atrophy (12 cases) and optic disc hypoplasia (3 cases)<sup>32</sup>. Microphthalmos was seen in association in association with spasticity in 4 patients and in 1 with atonic CP<sup>32</sup>. In one case, it was associated with uveal coloboma, anterior synechiae, shallow anterior chamber, disc hypoplasia and absence of septum pellucidum<sup>32</sup>. Optic atrophy was seen in 10% of children. They found that most of the optic disc abnormalities were associated with spastic CP<sup>32</sup>. The incidence of defects of colour vision was 8%<sup>32</sup>, which is about the same as that in the normal population<sup>58</sup>. Govind et al(1988) found optic atrophy in 10%, ptosis in 1.43% and coloboma of iris and choroid in 2.9% children with CP<sup>47</sup>. Katoch et al(2002) studied 200 patients of which 62 patients (31%) has a normal fundus picture<sup>35</sup>. Temporal disc pallor was present in 22 patients (11%). Diffuse disc pallor was present in 11 patients (5.5%)<sup>35</sup>. 1 patient had advanced glaucomatous cupping in both eyes. Myopic fundus was observed in 1 patient. Macular choroiditis, fundal coloboma and a salt and pepper fundus associated with deafness were present in 1 patient each<sup>35</sup>. Lew et al (2014) reported abnormal fundus findings in 6 patients of which 2 children had retinopathy of prematurity, which had been treated with laser photocoagulation therapy in both eyes, 2 had myopic crescent and 2 others had optic atrophy in both eyes<sup>52</sup>.

## Diagnosis and management:

Detailed history, neurological evaluation with developmental milestones by pediatrician and neuro-imaging (MRI Brain or CT Head) to document intracerebral

lesions for the objective diagnosis of SE/CP, BERA for the assessment of hearing and as an assessment of base-level brainstem assessment in these children and EEG for cases with associated epilepsy, IQ assessment for learning disabilities and ophthalmological assessment for visual milestones and development<sup>6</sup>.

The management of CP is multi-disciplinary<sup>59</sup>. The goal is to improve the quality of life of the child by managing treatable co-morbidities, providing support and therapies aimed at skill building within the framework of existing individual strengths and weaknesses<sup>59</sup>. With respect to the ocular manifestations, ocular misalignment can be managed with simple maneuvers like correction of refractory errors and patching for amblyopia<sup>59</sup>. If the deviation does not change or partially changes with optimum refractive correction or the eyes do not demonstrate any refractive error and both eyes are capable of taking up alternate fixation (thus precluding gross amblyopia), strabismus surgery is indicated to correct that component of deviation which is not ameliorated by refractive correction so as to restore back motor ocular alignment, important for optimum sensory rehabilitation<sup>59</sup>.

Thus in synopsis, SE is defined as non-progressive dysfunction of the brain<sup>1</sup>. Likewise, CP is a permanent, non-progressive disorder of movement and posture due to a lesion of the fetal or infant brain<sup>4</sup>. CP is a SE, the clinical pattern of presentation may change with time due to growth and developmental plasticity and maturation of the central nervous system over time<sup>4</sup>. During the period of infancy and childhood, modification in muscle tone and function are readily apparent<sup>4</sup>. Indeed the diagnosis of the type of CP and full extent of motor disability may not be evident until 3 or 4 years of age<sup>60</sup>. Such changes may result from the fact that deficits from damaged brain areas that normally should become functional at pre-determined ages, become manifest only at those ages<sup>60,61</sup>. It is at this time that the child should have his or her initial ophthalmological assessment. Ocular disorders are very common in SE including CP such as strabismus, refractive errors, amblyopia, gaze palsies, visual field defects<sup>4</sup>. CVI and DVM are also frequent in these children<sup>56</sup>. These disorders can easily be missed if the treating physician does not examine the CP child carefully or if the child is not sent to an ophthalmologist<sup>32</sup>. These problems are of immense concern for the complete clinical assessment, education and rehabilitation of these children. The ophthalmologist can help by giving an accurate appraisal of the visual, visuosensory and oculomotor assets of a patient with CP,

thus aiding the development of visually directed behaviour patterns<sup>32</sup>. Early diagnosis and proper management of ocular disorders also aids in promoting better parent-child relationship thereby reducing the difficulties which may exacerbate behavioral problems later<sup>21, 32</sup>. Modulation of muscle tone and functions are the mainstay of rehabilitative management in this condition<sup>32</sup>. It is in this context that visual behavior, its impairment and subsequent rehabilitation assumes great significance<sup>62</sup>. Development and cognition, both depend on strong sensory inputs. Vision is one of the most important sensory perceptions that aid developmental training and hence its correction, if subnormal or optimization is of paramount importance in the management of any patient with SE<sup>32</sup>. Visual loss or subnormal vision in SE may be due to cerebral damage and cortical visual impairment as a result of the same, or may be due to local anomalies in the eye, including anomalies associated with its optical character (refractive errors) or structural anomalies<sup>32, 51, 63</sup>. Usually children with CP are not examined with care due to a difficulty in making an assessment because of their mental and physical disability or with the idea that nothing much can be done to help them cope up with their already poor condition. Early diagnosis and appropriate management of ocular problems can help the child evolve to his maximum potential<sup>62</sup>.

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