Short Review Article

Visual Development: An Insight

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Abstract

Eyes are a part of our brain; they receive and reflect the intelligence of our thoughts and emotions. Normal vision is essential for a child's psychomotor, social and emo-tional development. Problems related to a slow or abnormal visual development are of a common occurrence in the paediatric population. Its early detection and appropriate management can prevent long term effects on the overall development of a child.

Keywords: *visual development, amblyopia, strabismus, convergence, stereopsis.*

Introduction

Visual development is a complex phenomenon; it is incomplete at birth and is influenced by many factors during the first few years of life. Anxious par-ents often bring their child to an ophthalmologist and ask, "Doctor my baby's eyes wander. Is his/her vision all right? or "I think he is squinting his one eye. " Being the treating ophthalmologist, it is important to know certain facts regarding visual development. Not only the parents need to be advised and re-assured but the underlying visual problem has to be managed appropriately and timely, otherwise it can result in long-term and even permanent visual deficit[1]

Milestones in Visual Development and their Implications

1. **At birth, the fovea as well as Lateral Geniculate Nucleus (LGN) in the thalamus is not developed**[2] so the baby only has a peripheral vision; it can see to the sides but cannot focus his/her eyes straight ahead or smile back at the parents because of a blurred central vision. By two months, LGN and its connections to the visual cortex in occipital lobe develop and infant begins to follow moving objects. As fovea fully develops by the age of three months[3], the baby starts to focus on a parent's face, toys and respond. Infants respond better to high contrast images, bold colours and bright objects. Parents should be advised to paint the baby's room in bright colours, decorate with contrasting shapes, hanging brightly coloured toys over the crib, adding new furnishings to the room to retain baby's interest, change the direction of the crib frequently so the baby can see new furnishings and keep a dim light on even at night to help stimulateits vision.As the visual acuity improves from 20/400 at birth to 20/25 by the age of six months, hand-eye coordination also develops and the infant can now locate toys and tries to grasp them. Six months of age is the time when a detailed ophthalmological examination should be conducted for all infants to rule out gross refractive errors, amblyopia, strabismus, and a definitive treatment started.

2. **Infants who suffer anoxia at birth or are premature (<32 weeks of gestation)**[4,5,6] and have a low birth weight, the development of brain is delayed. It has important centres for controlling eye movements, accommodation and convergence. Retina, being a neural structure, and the fovea, also have a delayed development. Such an infant will present with wandering eye movements, nystagmus, poor fixation or response to light and toys. A study conducted by Scott et al[7] showed that most of these infants have normal ERGs and VEPs as compared to their age-matched controls; they develop normal visually mediated responses by the age of 8 months. Hence, parents need to be reassured that the baby has a delayed brain development and as the general health improves, it will soon start focusing and smiling back. They need to be advised regarding a diet rich in Omega 3 and 6 Fatty acids[8,9] which are found in the phospholipid layer of retinal and neuronal membranes. Such a diet (mother's milk and enriched food supplements) help in the development of neural tissues in the retina and visual pathways.

3. **About 90% of infants are born hypermetropic due to a smaller axial length of the eyeball at birth.**[10] Stimulation of retina by light results in the growth of eyeball[11] and resultant emmetropia by the age of 1 year. Visual deprivation during this period will lead to a continued increase in axial length of and myopia. Myopia and strabismus are seen to be more prevalent in preterm babies as the visual system is still immature so the blurred vision leads to an increase in axial length of eyeballs.[12] Similarly, blockage of visual axis by the upper lid, as seen in common congenital problems like severe ptosis, blepharophimosis, capillary haemangioma will hamper light entering the eye and retinal stimulation, with resultant refractive errors and amblyopia. These problems should be managed rather urgently to keep the visual axis clear. Studies have proven that even peripheral stimulation of retina can influence refractive development.[13,14,15] The presence of a central corneal opacity, a central congenital cataract

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or a vitreous opacity hinder light stimulating the fovea. In such conditions, pupil should be kept fully dilated in that eye (with either 1% Homatropine eyedrops or 1/4% Atropine eyedrops once a day) so that light can enter the eye by-passing the opacity and stimulate the retina/ fovea, till that opacity is removed surgically.

4. **Anatomically, the bony orbits on a human face are pear shaped structures; the medial walls are parallel to each other while the lateral walls diverge at 90°.**[16] Similarly, both eyeballs, optic nerves and the surrounding rectus muscles are at a divergent angle to each other. After birth, in order to see the same object in space, both eyeballs have to converge to focus on that object and avoid double vision. Impulses of double vision go to the convergence centre in the brain, which then orders both the medial rectii to contract and the eyeballs converge. The phenomenon of convergence is the most essential component for the development of a binocular single vision in humans.[17] That is why medial rectii are always more fleshy, bulky and stronger that the lateral rectii. If there is an absence of convergence, a congenital exotropia appears while too much convergence results in a congenital esotropia. Since the fovea develops by the age of 3 months after birth, any comment on the presence or absence of strabismus should not be made prior to that age.

5. **Where is the Convergence Centre located?** The brain-stem reticular formation has many lower centres for regulating important body functions like cardiac activity, breathing and convergence. All these lower centres develop during the first three months of intra-uterine life. Convergence Centre is located in the rostral midbrain near the oculomotor nuclei.[18] It is very sensitive to anoxia which may occur during pregnancy due to maternal smoking (cigarette smoke contains 300 chemical toxins), alcohol, drugs like aspirin which delay the baby's growth and result in low birth weight infants. Many studies have confirmed higher incidence of refractive errors and strabismus in infants born to mothers who are active smokers or are exposed to cigarette smoke passively. Anoxia to a baby's brain during childbirth or early post-natal period due to high grade fever, fits or jaundicecan weaken or damage the convergence centre and the infant may either be born with a congenital exotropia or it may appear during the first 3-6 months of life. In any child presenting with a congenital strabismus, history of anoxia in the first 3 months of life should be particularly sought; the child may have normal higher mental functions and only the convergence may be strongly affected.

6. **The optic nerve is fully myelinated by the age of one year and the whole visual pathway is matured by this age and the child develops a visual acuity of 20/20 or 6/6.** This means that he/she can now see toys, lights or a parent walking towards him/her from a far distance. The first year of a child's life is the most critical period[19] for the development of visual pathway extending from eyes (including cornea, lens, vitreous, retina, optic nerve), onto the lower visual centres in the brain stem and higher visual centres in the occipital cortex. An insult during this period anywhere along the pathway will reduce a child's visual functions drastically.[7-12] months of age is the most important developmental period too; this is the time when a baby is learning to coordinate his vision with body movements. As the baby learns to crawl, the parents should be advised to play with him on the floor to help develop his hand-eye coordination and motor skills. This is also the time when parents should be extremely diligent to keep the baby out of harm's way as they are very eager to explore their environment and are extremely prone to injuries. All sharp objects should be out of their reach, cabinets need to be kept locked, electric sockets covered with tapes and barriers placed in front of staircases.

7. **The true critical period[20,21] extends from a period of three months till five years of age due to continued maturation of synapses in the visual pathway.** This means that although a 20/20 vision has developed by the age of one year, any insult to the visual pathway till the age of five years will result in regression of vision and development of amblyopia in that eye. During this period, particular care to the child's nutrition, general health, detection and correction of refractive errors is mandatory for a normal visual development.

8. **Another important characteristic of vision in humans is Binocularity[22]**, Depth Perception or Stereopsis (Stereo meaning 3 dimensional and opsis meaning sight). To see the same object in space, both eyeballs have to converge towards it and perceive that image: Simultaneous Perception. On human face, both eyeballs are placed at a distance of 6 - 6.5 cm. This results in a separation of image of the same object in space viewed simultaneously by both eyes. These two slightly dissimilar images are fused in the brain if they fall within its fusion-capacity i.e., in the Pannum's Fusion Area. The Fusion of two slightly dissimilar images perceived by two eyes, simultaneously, avoids diplopia. The impression of Depth is perceived as the right eye sees more on the right side of the object and the left eye sees more on the left side. This results in Retinal Disparity or separation of two images viewed by the right and left eye. The closer the two objects are to each other, the retinal disparity will be smaller; if the objects are farther away from each other, the retinal disparity will be larger. Hence an impression of depth (Stereopsis) is perceived when an object in space is viewed with both eyes. Hence these 3 characteristics of vision in humans are only possible because of Convergence of two eyeballs towards one single object in space.

9. **What is the significance of Stereopsis[23]???** The answer comes from observation of the animal kingdom. Animals like rabbit, chicken, cow, horse, goat and deer have their

both eyes placed on opposite sides of their heads. This provides them with the widest possible field of view in which they can see a predator approaching from a far distance and seek refuge (a protective phenomenon). Since they graze grass, leaves and do not have to hunt/ kill for food, they do not need depth perception and stereopsis.

On the other hand, predators (hunting animals) like lions, tigers, wolves and eagles have eyes placed on the front of their heads. This allows them a binocular single vision and depth perception to track their target precisely and keep it focused in their view while they are moving fast towards it to kill for food. Hence their field of view has been reduced in favour of stereopsis.

Similarly, humans are also predators / hunters. They need a precise, focused clear vision to carry out fine tasks. Hence we are blessed with a high level of stereoscopic vision at the expense of a relatively reduced visual field.

10. **Amblyopia and strabismus go hand in hand.**[24,25] which occurs first is controversial. The proper management of any patient presented with strabismus is not possible without treating the amblyopia.The concept of neuroplasticity proves that there is no age limit for improving a patient's vision and treating amblyopia. Studies reveal that there is no cell death or apoptosis in the neurons of the visual pathway; like the rest of the neuronal systems in the brain, visual pathway also has 3 orders of neurons: the retina, lateral geniculate body and the occipital cortex. They are found to be shrunken in an amblyopic eye and can be stimulated and activated to full function by strong and persistent stimulation. This can only be achieved if the inhibitory influence of the good eye has been blocked. Once the visual acuity of the amblyopic eye improves and binocularity has been restored, stereopsis also starts improving. This only happens if visual axis in both, equally seeing eyes are converging and are focused at a single object in space.

Conclusion

Normal visual development is achieved after birth in progressive steps. Problems related to abnormal visual development are common in infants, but their occurrence and longterm affects on vision can be minimised by early screening. A paediatrician should refer a baby early to an ophthalmologist if a blockage of visual axis is noted. A complete ophthalmological examination at 6 months of age for detection of refractive errors, amblyopia and strabismus is mandatory to prevent a permanent visual deficit.

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