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Neuroplasticity of the developing brain and child cortical visual impairment

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Summary. - Unlike lesions occurring in more steady-state conditions of the adult nervous system, lesions during early phases have additional effects in redirecting subsequent development. It is arguable that this implies enhanced opportunities to mitigate the deleterious effects of such lesions. Further delineation of plasticity and the application of the resulting insights promise therapeutically important advances. Considering the problem of the cortical visual impaired children in a neurodevelopmental key, we illustrate the necessity that we have as clinicians to diagnosticate as early as possible any case of cortical visual damage in order to foster continued development of the visual nervous system during the period of it greatest pliancy and give the children the maximum opportunity to achieve their still limited visual potential.

Key words: brain development, cortical visual impairment.

Riassunto *(Neuroplasticità del cervello in corso di maturazione e deficit visivo corticale).* - A differenza delle lesioni che avvengono nelle condizioni di maggiore stabilità del sistema nervoso adulto, quelle che intervengono nelle fasi precoci hanno effetti aggiuntivi nel modificare lo sviluppo successivo. Si può supporre che questo implichi maggiori opportunità nel mitigarne gli effetti lesivi. La migliore comprensione della plasticità e l'applicazione delle conseguenti conoscenze promettono progressi terapeutici importanti. Considerando il problema dei bambini con deficit visivi di origine corticale in chiave di sviluppo del sistema nervoso, si illustra la necessità, da un punto di vista clinico, di diagnosticare quanto prima ogni caso di danno corticale, allo scopo di sostenere il sottostante sviluppo del sistema nervoso visivo durante il periodo della sua maggiore plasticità, dando così a questi bambini la massima opportunità di raggiungere il loro, per quanto limitato, potenziale visivo.

Parole chiave: sviluppo cerebrale, deficit visivo corticale.

Introduction

The brain of the neonate is a much more plastic structure than that of the adult, both in normal development and in response to trauma.

We know that cellular development and synaptogenesis are compromised when neonatal tissue is exposed to hypoxic conditions and that there are critical periods of sensitivity in which processes undergoing rapid maturational change are particularly vulnerable: the extent of the perturbation depends on the time of the noxa respect to the stage of brain development [1].

This concept is true for all the brain systems, in particular it has been investigated in the visual system since the classical experiments of Wiesel and Hubel in 1963 [2].

Much of the basic anatomical structure on the visual pathway is constructed before birth. A wave of maturation sweeps through the system, from the eye to the visual cortex, the correct formation of connection depending on precisely timed interactions between axons and their targets. Competitions between growing axons, cell death, axon withdrawal, trophic interactions play a still not completely understood role in constructing the visual pathway and laying down basic "maps" of the visual field before birth.

At the level of the visual cortex, synaptic plasticity continues after birth and may permit cortical neurons to refine their processing capacities on the basis of information provided by the visual environment [3].

In a recent study of Klekamp on quantitative changes during postnatal maturation of the human visual cortex, its volume is characterized by an overshooting growth pattern at 8 postnatal months and by loss of a substantial proportion of its neuron. The highest rate of reduction in neuronal numbers is observed in layers II-IVa, with other layers showing a more gradual postnatal decrease [4].

Synaptogenesis begins at 28 weeks gestation, it reaches its maximum 8 months postnatally and then it followes gradual loss of synapses, until adult synaptic density is reached at 11 years [5]. Dendritic growth of cortical neurons commences at 25 weeks gestational age, is very active around term and continues during the first postnatal year.

About the basic mechanisms of neurogenesis, there is deep interest in investigating the "regressive events": the naturally occurring neuronal death and the synapse elimination (for review see [6]).

Oppenheim writes: "With regard to mechanisms, the demonstration that NGF is a trophic molecule for the survival of sympathetic and dorsal root ganglion cells has provided a rational basis for arguing that competition of neurons for limited amounts of target-, afferent-, or glia-derived trophic factors may be a primary mechanism underlying naturally occurring cell death in many other populations of neurons" [6].

In any case, though there is regrettably little concrete data on this point, it seems plausible hypothesize that these regressive events are modified after a early brain injury and can attenuate or compensate the structural damage [7].

This can give an account of the variability of the functional performance in children with brain damages [8].

We must remember that, unlike in the peripheral nervous system, where sprouting and surviving motor neurons can restore function, such regenerative attempts within the central nervous are incomplete and do not compensate for the initial insult [9, 10].

Cortical visual impairment in children

Cortical visual impairment (CVI) is defined as a visual loss caused by a disturbance of the posterior visual pathway and /or cortex.

The vast majority of patients are not totally blind. There are different opinions about this controversial topic: in many studies is reported that in early infancy visual function is subserved predominantly by the extrageniculostriate visual pathway [11]; others conclude that useful visual function is preserved only when a critical amount of area 17 is spared: the subcortical second system may participate in the generation of visual evoked potentials, but is uncapable of conscious visual perception [12].

The causes of CVI vary. Relatively minor changes in the topography of damage to the visual cortex and posterior visual pathways result in substantial differences in visual behaviour [13].

The most common aetiology of CVI in the study of Flodmark (at the moment the largest and most comprehensive study on the subject: 134 children) is perinatal asphyxia [11], devided in asphyxia occourred to preterm and term children (Table 1).

Because of the differences due to changes in the vascular anatomy, the premature brain develops an hypoxic-ischaemic brain injury located specifically in the periventricular white matter affecting the geniculo-calcarine tract; the born at term children with CVI develop hypoxic-ischaemic brain injury in the visual cortex.

Abnormalities of neuronal migration, trauma, infections and hydrocephalus with episode of shunt failure are the other most common causes of CVI.

It is worthy to say that older children though profound, diffuse cerebral atrophy (CT findings) rarely acquire permanent CVI. The most plausible explanation is that the visual pathway and visual cortex become more resistant to hypoxic damage with increasing age [14].

The extent and location of permanent brain damage, as seen on CT scan, is important about the prognosis for visual recovery: children with CVI and normal or mildly abnormal CT scans often (almost 50 per cent of cases) recover their visual acuity though with residual visual motor perceptual difficulties [15].

Van Hof-van Duin and Mohn consider the severity of visual defects after perinatal hypoxia to be related to perinatal events and neurodevelopmental outcome [16].

Visual development is a continuing process dependent at every point on the capacity of the input pathways and the level of function within the visual nervous system (Table 2).

Table 1. - Aetiology, CT findings, visual loss and ocular abnormalities (no. = 70)

Aetiology	no.	CT findings
Asphyxia		
preterm	16	PVL
term	17	Diffuse tissue loss, occipital infarcts only
Acquired	1	Diffuse tissue loss
malformation	10	Migration defects
trauma	8	Variable pathology
infection	8	Variable pathology
shunt failure	6	Bilateral occipital infarcts with dilated lateral ventricles
Miscellaneous	4	Diffuse tissue loss, unilateral porencephalic cyst, normal

Modified from Flodmark *et al.* 1990 [11].

Table 2. - Testing visual acuity

A gross estimate of the child's vision is made by watching the ability to:
- follow a face;
- respond to facial expression;
- reach for a small toy;
- follow a moving object (coloured balls or finger-puppet).

The test chosen for formal vision screening will depend on the age of the child.

At six weeks a baby should:
- follow a suspended coloured ball in an arc through 180° at a distance of 30-45 cm while lying on his back;
- follow a face at this distance;
- watch his mother's face when held in her arms.

From six to eighteen months the Stycar balls (a graded series of white balls ranging in diameter from 63 mm down 3 mm) are a useful test of distance vision at 3 meters.

Theoretically, the vision of severely visually impaired children may remain suboptimal throughout the early months and their full potential for vision may never be achieved.

Therapy directed at achieving maximal levels of vision throughout infancy is a logical way of ensuring that the highest possible quality of vision is available at all times for visual and general development.

As the first year is the critical period for neuronal networks and coding templates of the visual nervous system, the first year is also the most appropriate period to implement a programme to promote visual development, the one during which it is likely to prove most effective.

The study of Sonksen *et al.* [17] about a developmentally based program for visual development aimed at evaluating the results and to determine wheter outcome is influenced by the age at introduction or the development status of child, shows a consistent difference between the treated and control groups; furthermore it has been confirmed the importance of as early as possible, in any case during the first 13 months of life, intervention in order to foster continued development of the visual nervous system during the period of its greatest pliancy.

This gives severely visually impaired babies the maximum opportunity to achieve both their limited visual and their general developmental potential.

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