Neonatal Rehabilitation and Outcome

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9.1 Introduction

Neonatal rehabilitation includes strategies to restore the developmental milestones and improve the neurodevelopmental outcome in neonates who have suffered injury to the brain before, during or after birth.

Common causes of neonatal morbidity include preterm birth complications, intrapartum-related factors: hypoxic–ischemic encephalopathy (HIE), infections (sepsis, meningitis and neonatal tetanus) and other conditions: jaundice and congenital infections (cytomegalovirus, toxoplasma, syphilis, and rubella).

Neonatal encephalopathy is diagnosed in neonates with significant neurologic dysfunction, including respiratory difficulties, altered tone, low consciousness, or seizure activity. It is the best predictor of Cerebral palsy in term infants, regardless of the cause of encephalopathy [1].

Before planning rehabilitation, it is important to learn about the following terms which will affect the overall neonate outcome:

9.2 Growing Brain and Neural Plasticity

In infancy, the sensory and motor systems interact with the environment and construct more complex systems, and thus learning is achieved. Neural processes such as the formation of multisensory connections and higher order networks are all built upon the more basic functions (e.g., hearing, vision). Preterm birth and its complications or injuries resulting from insults such as prolonged hypoxia or illness change the order of normal neurodevelopment. Growth and environment are critical for

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early neurodevelopment making nutritional, social–emotional and physical environmental factors as essential components of evaluation and treatment in infancy [2]:

- Neural plasticity is the capacity of the nervous system to modify itself, functionally and structurally, in response to experience and injury.
- It is a key component of neural development and normal functioning of the nervous system as well as a response to the changing environment, aging or pathological insult.
- Plasticity is necessary not only for neural networks to acquire new functional properties but also for them to remain robust and stable [3].
- It is the process of reorganization of neural connections after injury or experiences and can be harmful also. Compensation for a brain lesion or a poorly functioning pathway can be re-established at the expense of another pathway, even of a higher order process.
- Hence, a rehabilitation expert should have an in depth knowledge about the good and ill effects of neural plasticity before applying its fundamentals for neurorehabilitation [2]

9.3 Development Process of a Child

Development is a continuous process; it proceeds stage by stage in an orderly sequence, despite individual variations. As the nervous system matures, increasingly complex behaviors unwind. Each stage of development represents a higher level of maturity where features are qualitatively different, yet dependent and derived from earlier stages [4].

There are four components or domains of developmental growth: physiological, sensorimotor, Cognitive and psychological.

1. **Physiologic domain**: at birth, a full-term neonate adapts to the new environment and is independent in respiration, circulation, digestion and temperature regulation.
2. **Sensorimotor domain**: newborns and neonates exhibit specific behavioral states of arousal: deep sleep, light sleep, drowsy, quiet, alert, active, awake and crying. There is a gradual transition from one state to another, and the response to stimulation is influenced by the neonate's behavioral state.
   (a) **Gross motor skills**: neonate's gross motor activity is developed from movement patterns that begin in the intrauterine environment and from the maturation of reflex behavior which is under control at two levels—spinal and brainstem. Apart from reflex behavior, a neonate demonstrates orientation, attention, and habituation to visual, auditory, and tactile stimuli. Motor responses in head control, sitting, rolling, and locomotion continue to develop from simple to complex skills. At 4 weeks, the neonate can move its head side to side. Head lag is noted from pull to sit position.
   (b) **Fine motor skills**: grasping reflex is present at birth. This allows the infant to have automatic contact with anything placed in the palm, though the hands are predominantly closed and the contact with the object is more with

the eyes than with hands. They look, stare and track objects within their visual fields.

3. **Cognitive domain**: According to Jean Piaget's theory, a child from birth to 2 years of age responds to and learns about the environment directly through sensations and motor responses. The emphasis is on sensory, movement and manipulative experiences with objects.
   (a) This is the shortest period of mental development but is the most active.
   (b) This accounts for the reflexive stage with simple biologic reflexes that are primitive, general, and related to survival.
   (c) Sucking and palmar reflexes which help to promote oral and manipulative exploration are most critical to early mental development.
   (d) The taste of food later in life depends on kinesthetic sensations derived from reflexive movements of sucking.
   (e) The development of communication is also related to the infant's cognitive abilities. The ability to produce different sounds is evidenced in crying. Lack of crying ability indicates neurologic impairment.
4. **Psychological domain**: after birth, there is emotional transition as the baby moves out of the protected environment of the womb. A sense of trust and mistrust starts developing. The ease of feeding, depth of sleep, and relaxation of bowels are signs of neonate's development of trust which is highly dependent on its relationship with primary caregivers. Position of face and early eye-to-eye contact between parents and neonate, help in the attachment process.

9.4 History Taking

- A detailed neonatal history is essential, including birth age and weight, Apgar scores, onset and success of breastfeeding, medications, and supportive measures given while hospitalized.
- Age, weight, and condition on discharge, means of feeding, need for ventilatory or other support at home, help predict subsequent, continuous, or recurrent problems.
- Weak lip closure, weak sucking force, and inadequate feeding may be preliminary signs of oral-motor dysfunction.
- Neonatal seizures may signal perinatal brain damage.
- Prematurity, particularly with low birth weight, is a frequent cause of cerebral palsy [2].
- Large birth weight may lead to intrapartum trauma, brachial plexus injury, and palsy, particularly with breech or other fetal malposition.

9.5 Examination

In newborns and young infants, state of alertness, activity, and comfort influence muscle tone. If the baby is restless and crying (anxious, upset), examination for muscle tone should be postponed.

Fig. 9.1 High-risk neonate with increased tone of all four limbs

- Increased tone is the symptom of corticospinal or basal ganglion damage (Fig. 9.1).

Intrauterine and neonatal insults carry a high risk of substantial long-term neurological morbidity.

- Neurological abnormalities should always be routinely sought as part of neonatal care in babies who survive significant Hypoxic Ischemic Encephalopathy.
- Persistent generalized disturbances of tone, seizures, continued irritability or decreased alertness, persistent asymmetry of posture, movement and delay in establishing efficient feeding, are all indicative of neurological abnormalities of the infant beyond the neonatal period [5].

9.6 Posture and Movement Patterns

A fetus in the womb is flexed with midline orientation of the head and extremities.

- Due to effects of gravity, prematurity, illness, low tone, primitive reflexes and immature neuromotor control, the resting posture of a neonate without therapeutic positioning will be flat, extended, asymmetrical with the head to one side and with the extremities abducted and externally rotated.
- Lack of appropriate positioning can create short-term and long-term functional problems even in the absence of overt brain pathology [6].

The best known neuromotor assessment is the general movement assessment (GMA).

- General movements are the most frequently used movements from early fetal age until 3–4 month post-term.
- Quality of these movements provides information about the integrity of the brain, especially about the connectivity in the periventricular white matter [7].
- Movements are assessed when the neonate is awake, calm, alert, and lying on the back.
- Baby should not have any toys or pacifiers and parents should not be interacting with the baby.
- The baby is videoed for 3–5 min and used for assessment and scoring.
- Babies with absent or abnormal general movements are at higher risk of neurological conditions, particularly, cerebral palsy.

9.7 Muscle Tone

- Muscle tone gradually increases with age, in caudal-to-cephalic (feet-to-head) and distal-to-proximal (extremities-to-trunk) directions.
- Active muscle tone, observed during spontaneous movement or elicited by righting reactions when the infant is handled, develops before passive flexor tone seen at rest [8].
- Hypotonia is normal for extremely preterm neonates, and at term demonstrates greater extension and less physiologic flexion than a full-term newborn.
- Twitches, tremors, and startles are common in preterm infants, but movements typically become even and tremors less prevalent as term equivalency nears.
- Assessment of muscle tone also depends on state of arousal and medical status. A preterm neonate may be active when awake but hypotonic if assessed while drowsy or asleep.
- Evaluation of muscle tone is not accurate when the baby is ill. It changes as the baby recovers.
- Many medications have neuromotor side effects [9].
- Atypical findings and unusual movement patterns improve with maturation and physical recovery.

Bone layout and joint mobility change during the growing years:

- Full-term infants have predominant flexor tone and lack around 25° of elbow extension.
- Joint hyperextensibility and hypotonia allow increased passive motion in preterm infants.
- **Scarf sign** is a good example of excessive joint mobility in premature babies. Holding the baby's hand, the examiner draws one arm across the chest, like a scarf, toward the contralateral shoulder, round the neck. In premature infants, the

elbow crosses the midline, indicating hypotonic laxity of the shoulder and elbow joints.

- In full-term neonates, due to early flexor tone predominance, there is incomplete hip extension with a mean constraint of 30°, which decreases to less than 10° by 3–6 months [10]. At birth and during early infancy, hip external rotation surpasses internal rotation due to early hip flexion attitude. Differences between bilateral hip abduction, apparent shortening of one leg and asymmetric gluteal and upper thigh skin folds are highly suggestive of congenital or acquired hip dysplasia or dislocation [11]. Alignment of the femoral neck in neonates is consistent with prenatal coxa valga and increased anteversion. Femoral inclination is 160° and the angle of anteversion is 60°. Respective adult measurements of 125° and 10–20° develop postnatally and are accelerated by weight bearing.

Screening of eyes and ear are part of routine examination at birth to rule out congenital visual impairment and hearing loss, respectively [12].

Early onset brain damage, especially of the prefrontal cortex, can result in behavioral problems, making assessment exceedingly difficult during the early years, especially when other impairments (motor and cognition) are also present.

9.8 Neonatal Rehabilitation - Early Interventions

The aim of neonatal rehabilitation is early intervention in the high-risk neonate in all areas of development to achieve functional independence as an individual. This should be an integral part of the management for early and effective planning from day one for on-going care.

Early intervention is defined as child-oriented training activities and parent-oriented guidance activities which are implemented after identification of the developmental condition. Early age period from 0 to 3 years is the most appropriate period to lay the basic foundation for further development and learning as brain is characterized by high plasticity during this period. Early intervention involves interaction of the child, parents, family, society, and environment. These services are designed to identify and meet child's needs in five developmental areas:

(a) Physical
(b) Cognitive
(c) Communication
(d) Social or emotional development
(e) Sensory and adaptive development

Early intervention includes provision of services to children with developmental delays or disability and their families for the purpose of lessening the effects or burden of the condition. Early intervention can be **remedial** or **preventive** in nature—remediating the existing developmental problems or preventing their occurrence [13]. All children who are subjected to developmental risk or developmental disability should have access to these services.

1. **Caregiving:** the sense of touch is highly developed in utero, and gentle human touch after birth, provides consistent positive tactile inputs. Caregiving procedures may contribute to the neonate's physiologic instability (increased heart rate, fluctuations in blood pressure, alterations in cerebral blood flow, and hypoxemia), motor stress, energy depletion, and agitation. Caregiving based primarily on fixed schedules for vital signs and feeding often delays the caregiver's response to baby cues and thus baby's efforts to communicate are wasted.

   Synaptogenesis (formation of billions of connections between neurons) is a primary ongoing event in the development of brain and sensory system during the last trimester. After 28 weeks of gestation, endogenous synaptogenesis generates brain complexity and plasticity, and occurs only during REM sleep. Undisturbed sleep is **absolutely essential** for normal development of the fetal brain and sensory systems during the last trimester.
   Caregivers should focus for an optimum sleep of their child.

   (a) Unnecessary handling and movement should be avoided.
   (b) Caregivers should prepare the baby for touch or movement by speaking softly and containing extremities during movement and lifting.
   (c) Social touch and noninvasive care giving procedures can disturb and stress neonates, requiring caregiver efforts to comfort and promote recovery.
   (d) Comfortable bedding, containment, parental skin-to-skin holding (kangaroo care) and reduction of environmental light and sound are supportive measures [14].

   Maternal depression after birth of a high-risk child increases stress and delays parental responsibilities:
   (a) Parents have multiple roles as caregivers, educators, and facilitators of their child's development.
   (b) They should be encouraged to ask questions about what they understand and want to know.
   (c) The response of the treating physician and other staff involved in care of the child should be honest and understandable.
   (d) Parents are often frustrated and anxious when information is incomplete and conflicting.
   (e) Printed material such as pamphlets/booklets with information about early intervention in simple language along with pictures can be provided for parent education.
   (f) Parent support groups/peer group counselling can also be helpful in providing information and support.
   (g) Inclusion of siblings, extended family members, and volunteers should be encouraged.

   Parents should be helped with the following for a long-term positive outcome:
   (a) To gain competence and confidence in recognizing and responding to their infant's cues of stress
   (b) Providing therapeutic positioning and developmentally supportive handling
   (c) Regulating sensory input to avoid overstimulation

Fig. 9.2 Mother–infant bonding

(d) Facilitating functional oral feeding
(e) Meeting the neonate's long-term developmental needs
(f) Promoting parent–infant attachment (Fig. 9.2).

2. **Developmental stimulation** is not appropriate until the neonate is near term and sufficiently stable medically, for seeking attention and interaction. Each child is different. Stable term infants may demand more attention. Prolonged crying must not be ignored. Lullabies and musical toys can be used for stimulation [9].
3. **Touch, Smell and movement sensations:** These sensations help the newborn to maintain contact with the caregiver. Touch or Tactile sensations are critical in establishing a mother infant bond and help in forming feelings of security in the infant. Tactile system plays an important role regarding emotions as it is directly involved in making physical contact with others. Proprioception also plays an important role in mother infant relationship. The phasic movements of the infant's limbs generate additional proprioceptive inputs which help in development of body awareness [4]. Of all the sensory systems, Vestibular is first to mature. It is fully functional at birth, although its integration with visual and proprioceptive systems continues through childhood. This is seen when rocking and carrying to calm the baby. Lifting into an upright posture against the caregiver's shoulder increases alertness and visual tracking.
4. **Oromotor impairments** can cause feeding difficulties in preterms, who may have encephalopathy. Rehabilitation aims at re-establishing patterns of suck–swallow–breathe coordination and increased endurance and efficiency during oral feeding.
5. **The visual and auditory systems are immature at birth—**the neonate orients to some visual and auditory inputs, particularly human face, and voice. For a proper developmental care, there should be interaction among the neonate, family, and surroundings wherever the neonate is cared for. The surroundings should be lively and positive and promote involvement of family members as primary caregiver hospital environment (Fig. 9.3).

Fig. 9.3 Interaction by paternal and maternal grandmothers in an Indian setting

A preterm infant's immature CNS is generally competent for protected intrauterine life, but is not sufficiently developed to adjust to the demands of extrauterine life, which may stress the already vulnerable and disorganized CNS. Excessive sensory stimulation can cause insults to the developing brain (from repeated hypoxic episodes related to stress) and create maladaptive behaviors that contribute to later poor developmental outcome [15]. It becomes a priority to reduce avoidable stressors and help the preterm baby remain calm, without sleep deprivation.

Auditory stimuli: sufficient opportunities should be provided to hear interactive parent voices by the high-risk neonate [15]. Audio recordings should be played only for brief periods, be less than 55 dB and at a reasonable distance from ear, and should not affect sleep.

Visual stimulation: protection of eyes from direct light exposure and avoid abrupt light fluctuations [16]. Black & white patterns drawn on a cardboard placed near the child can be used for visual stimulation.

Developmental interventions that support neonate's physiologic stability and brain development include:

(a) Proper lighting (bright lights can disrupt sleep)
(b) Sound modifications (loud noise can contribute to apnea, bradycardia, sleep disruption)
(c) Therapeutic positioning, nurturing touch, non-nutritive sucking
(d) Alteration of caregiver timing and handling techniques
(e) Preservation of sleep and
(f) Increased family involvement

6. **Therapeutic positioning:** positioning replicates the in utero posture. External support and positioners can provide a temporary substitute for the premature neonate's poor motor control. Proper positioning is an important neuromotor developmental intervention to minimize positional deformities and to improve muscle tone, postural alignment, movement patterns, and developmental milestones [9]. Active infant movement is potentially important for normal muscle tension on bone and necessary for mineralization and bone density. Mother should be given training regarding holding techniques specially in neonates with increased tone.

Fig. 9.4 Proper posture and positioning

7. **Range of motion:** passive range of motion (PROM) (Fig. 9.4) may be appropriate for neonates who demonstrate structural or neuromuscular limitation of movement and are stable enough to tolerate a rehabilitation approach. It is less beneficial in hypertonicity neonate, where sustained stretch is advocated. Gentle PROM can be useful in sedated neonates to avoid development of contractures.

Gentle PROM exercises

8. **Massage:** massage is an art and a science that the caregiver should be taught in terms of techniques, precautions, and warning signs. This allows an active engagement and bonding between the neonate and the caregiver.
9. **Splinting:** splinting is rarely needed in neonates as rigid contractures are uncommon and neonates are notably flexible. Over time improvement is achieved with gentle stretches, and therapeutic positioning. Rigid splints inhibit spontaneous movements and should be avoided for long periods of time. Protecting skin integrity and encouraging active movements are priorities in designing a neonatal splint. Simple splints made of light material-like foam is well-tolerated.
10. **Feeding:** breast milk is the optimal nutrition for neonates. Any breast milk the child receives is valuable. Mothers of preterm or ill infants who are educated about the benefits of breast milk often choose to pump milk for

their infants; many are unable to maintain sufficient lactation for successful or exclusive breastfeeding at discharge. Early initiation of frequent breast pumping, skin-to-skin holding as soon and as often as possible, non-nutritive sucking at breast (breast pumped first, although the breast is never truly empty and milk may "letdown") and establishing the basics of breastfeeding [17]. Milk banks are now associated with Neonatology units in tertiary care Hospitals.

9.9 Outcome

- Prediction of future developmental outcome is difficult, as change is one of the main characteristics of the developing brain.
- Many neonates survive major insults without any evidence of impairment because of the plasticity of the developing brain and improvements in medical care.
- In some newborns, insults can cause varying degrees of long-term neuro developmental impairment, with huge socioeconomic burden, especially in resource-poor countries, and affect the global burden of disease as it contributes to both premature mortality and long-term disability.
- There is less information about the severity and distribution of long-term impairments after intrauterine or neonatal insults. Few studies provide supportive evidence that intrauterine and neonatal insults result in significant long-term neurological morbidity and that these insults have a high risk of affecting more than one domain [e.g., cognitive impairment, motor impairment, hearing and vision loss [18]].
- Presence of widespread neural impairment reduces the probability for neuro plasticity of the nervous system and chances of beneficial effects of intervention decrease with the extent of brain pathology.
- High-risk neonates are at increased risk of developing behavioral problems throughout childhood, such as autism spectrum disorder, potential precursors of anxiety and depression in childhood and adolescence [2].
- Stress during early life is known to have lifelong consequences, as it induces permanent changes in the brain, especially the mono-aminergic and dopaminergic systems. Alterations in the dopaminergic system are associated with impaired motor learning [19].

Rehabilitation, by early intervention, helps in attainment of developmental milestones and prevention of development of complications, such as contracture in limbs and pressure sores.

Along with motor outcome, improving cognition, socio-emotional skills and mental health is the focus of early intervention programs.

Family counseling and timely guidance improve outcome of high-risk babies.

These include providing:

1. Family education concerning the issues being faced by the child and its management
2. Peer counseling by caregivers of other high-risk babies
3. Education to caregivers regarding importance of sensory and environmental stimulation
4. Basic rehabilitation in home settings, such as proper handling, positioning, therapeutic exercises, daily care (bathing, dressing, feeding), and use of simple aids
5. Family support essential for positive outcome

9.10 Pearls of Wisdom

1. Proper Antenatal care with identification of high-risk pregnancies and parental counseling regarding care of the neonate is a must.
2. Timely referral to rehabilitation specialist is the need of hour.
3. Awareness regarding rehabilitation and timely utilization of these services to prevent secondary complications of motor impairments (contractures, feeding difficulties, later psychological, and cognitive impairments).
4. District health care workers should be trained in basic rehabilitation techniques and motion exercises.
5. The plastic changes may fade away the affliction present at early age—infants grow out of their deficit. The reverse is also possible: children may be effectively free from signs of dysfunction at early age, but grow with functional deficit due to age-related increase in complexity of neural functions [20].
6. In view of the poor outcome, prevention, and improved treatment of complications during birth and neonatal period, along with research into adjunct treatment approaches cannot be overemphasized [21].
7. Involvement of caregivers is the key to successful rehabilitation program.

References

1. Alexander MA, Mathews DJ. Pediatric rehabilitation. Principles and practice. 4th ed. Demos Medical; 2009.
2. Maitre NL. Neurorehabilitation after neonatal intensive care: evidence and challenges. Arch Dis Child Fetal Neonatal Ed. 2015;100(6):F534–40. https://doi.org/10.1136/archdischild-2013-305920. Epub 2015 Feb 20.
3. von Bernhardi R, Eugenín J, Muller KJ. The plastic brain. Springer; 2017. https://link.springer.com/book/10.1007/978-3-319-62817-2
4. Nuse Clark P, Allen S. Occupational therapy for children. Am J Occup Ther. 1988;42(6):359–63.
5. Sabrine N, Singh J, Sinha SK. Medical management of birth asphyxia. Indian Pediatrics. 1999;36:369–76.
6. Spear ML, Leef K, Epps S, etal. Family reactions during infant hospitalization in the neonatal intensive care unit. Am J Perinatol 2002;19: 205–213.

7. Prechtl HRF. Qualitative changes of spontaneous movements in fetus and preterm infant are a marker of neurological dysfunction. Early Hum Dev. 1990;23:151–8. https://doi.org/10.1016/0378-378290)90011-7.
8. Blackburn ST. Neuromuscular and sensory systems. In: Blackburn S, editor. Maternal, fetal, and neonatal physiology: a clinical perspective. 2nd ed. St. Louis: Saunders; 2003. p. 546–98.
9. O'Brien S. 'Neonatal intensive care unit': occupational therapy for children. 6th ed. Mosby; 2010.
10. Steindler A. Kinesiology of the human body. Springfield, IL: Charles C Thomas; 1955.
11. Tachdjian MO. Pediatric orthopedics. 2nd ed. Philadelphia: WE Saunders; 1990.
12. Rashtriya bal swasthya karyakram: Ministry of Health & Family Welfare, Government of India; 2017. http://nhm.gov.in/nrhm-components/rmnch-a/child-health-immunization/rashtriya-bal-swasthya-karyakram-rbsk/background-html.
13. Organization of Early Intervention Services. National Institute for the Mentally Handicapped Secunderabad; 2008
14. Gardner SL, Goldson E. The neonate and the environment: impact on development. In: Merenstein SL, Gardner GB, editors. Handbook of neonatal intensive care. 6th ed. St. Louis: Mosby; 2006. p. 273–349.
15. Graven SN. Sound and the developing infant in the NICU: conclusions and recommendations for care. J Perinatol. 2000;20:S88–93.
16. Graven SN. Early neurosensory visual development of the fetus and newborn. Clin Perinatol. 2004;31:199–216.
17. Howe TH, Wang TN. Systematic review of interventions used in or relevant to occupational therapy for children with feeding difficulties ages birth–5 years. Am J Occup Ther. 2013;67:405–12.
18. Kolb B, Mychasiuk R, Williams P etal. Brain plasticity and recovery from early cortical injury. Dev Med Child Neurol 2011; 53(Suppl 4):4–8. https://doi.org/10.1111/j.1469-8749.2011.04054.x
19. Weinstock M. The long-term behavioral consequences of prenatal stress. Neurosci Biobehav Rev. 2008;32:1073–86. https://doi.org/10.1016/j.neubiorev.2008.03.002.
20. Hadders-Algra M. Two distinct forms of minor neurological dysfunction: perspectives emerging from a review of data of the Groningen Perinatal Project. Dev Med Child Neurol. 2002;44:561–71. https://doi.org/10.1111/j.1469-8749.2002.tb00330.x.
21. Mwaniki MK, Atieno M, Lawn JE, et al. Long-term neurodevelopmental outcomes after intrauterine and neonatal insults: a systematic review; 2012, p. 379. www.thelancet.com.