REVIEW ARTICLE

Early Developmental Care Interventions of Preterm Very Low Birth Weight Infants

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The preterm very low birth weight infants are at high risk of developing neurodevelopmental delay despite little or no medical complications at the time of birth. The care and interventions of such infants have an impact on the pre-existing risk. The Developmental Care Interventions (DCI) are the range of treatment strategies aiming to alleviate the risk thereby improving neuro-developmental outcomes. The objective of this review is to appraise the range of such interventions for preterm very low birth weight infants reported in the literature. This review will help clinicians to adopt developmental intervention strategy to improve the neuro-developmental outcomes of their NICU graduates.

Keywords: Developmental care, NICU, Neuro-developmental outcomes, Multi-modal sensory stimulation.

The in-utero early sensory experiences of the fetus are essential for normal brain development during the perinatal period. The premature infant (considered as extra-uterine fetus) is deprived of in-utero sensory experiences, rather exposed to unusual sensory stimuli in the Neonatal Intensive Care Units (NICU) that pose risk to the developing brain in terms of adverse neuro-developmental outcomes [1]. Developmental care interventions (DCI) is an umbrella term comprising of several interventions aiming to facilitate the infant cope with the environmental demands and also to modulate the sensory experiences as a result of its early exposure to the same. The expected outcome of DCI is improvement in overall physical, cognitive, social and emotional development of the new born. The reviews on DCI to high risk infants indicate that there are controversies in the type, mode and timing of stimuli presented, given the complex nature and heterogeneity of interventions. Some even argue that the very purpose of DCI can be detrimental to the growth and development of high-risk infant if not delivered properly. Till date the evidence on the effectiveness of these interventions is inconclusive [2,3].

We herein provide the recent updates on developmental care interventions of preterm very low birth weight infants, its clinical importance and available best evidence. The role of mother and the family for the success of DCI program will also be appraised.

Typically DCI interventions involve presentation of multi-modal sensory experiences and modifications of NICU environment. Such interventions are more often extended beyond the NICU stay of the neonates and are carried out throughout the infancy. However for the convenience of review, the developmental interventions are discussed under the major sensory modality with which the preterm infants are stimulated.

TACTILE STIMULATION

The fetus during the prenatal period receives rich tactile sensory experiences as it is bathed by the amniotic fluid. During NICU stay the preterm infants are deprived of constant tactile stimulus of amniotic fluid and are also exposed to varying touch stimulus (other than the mother) on handling during routine medical and nursing procedures. Several studies have made consistent observations on adverse effects of such handling procedures that include hypoxia, bradycardia, sleep disruptions, increased intracranial pressure and behavioral agitation. Thus supplemental tactile stimulation is indicated at the same time ensuring minimal and gentle handling [4].

SWADDLING

During the non-contact period of the infant and the mother in NICU, the preterm infant is deprived of the tactile stimulus. This can be overcome by swaddling that involves wrapping the infant with sheets of cloth or blanket and is done prior to positioning on cradle board. This method is also referred to as tucking, containment, binding or bundling. The systematic review on swaddling

reports that swaddled infants have longer sleep and are less aroused; have improvements in physiological (lower heart rate) and behavioral states (calms infants, induces and prolongs sleep, fewer startles); alleviates pain and prevents hypothermia. The study also reported improved neuromuscular development and motor organization following swaddling [5]. Negative effects of swaddling include respiratory infections because of tightened swaddling; increased risk of sudden infant death syndrome (SIDS) when swaddling is combined with prone positioning and increased risk of hip dysplasia as the hip is maintained in extension and adduction in swaddled position. It also increased risk of hyperthermia when misapplied and decreased postnatal weight gain because of early separation from mother, longer sleep, less nursing requirement and delayed breast feeding [6].

GENTLE HUMAN TOUCH AND MASSAGE

Infant massage therapy involves gentle touch, stroking or rubbing the infant with hand using light/moderate pressure. Gentle Human Touch (GHT) approach involves placing one hand over the infant's head and other over the lower back extending to the buttock for 10-20 minutes. A study on GHT reported that this type of touch has no adverse effects on mean heart rate or oxygen saturation levels; however, such touch resulted in increased respiratory regularity, improved sleep cycles (decreased active sleep and increased quiet sleep), motor activity and behavioral distress during periods of gentle touch [7]. A modification called Touching and Caressing - Tender in Care (TAC-TIC) therapy has been reported that enhances mental development, improve physiological states and behavioral reactions, improve sucking behavior and cognitive performance within the neonatal period [8].

Several studies have reported the potential benefits of massage with or without kinesthetic stimulation [9]. The systematic review on massage reported improved weight gain, improved physiological and behavioral states, decreased stress behaviors, improved pain alleviation, reduced postnatal complications, shorter hospital stay and improved performance in developmental scores; however it lacked strong evidence [10]. Some studies have shown that the massage benefits are more pronounced when massage is combined with usage of specific oils [11]

PAIN MANAGEMENT

Sleep cycles and awake/alert states of the newborn are essential for optimal neuro-developmental outcomes. The medical and nursing procedure on preterm infants elicits pain and disturbs the sleep-awake cycle that would result in adverse neuro-developmental outcome and hence there is a need to alleviate pain [12]. A systematic review that included 51 randomized controlled trials reported sufficient evidence to recommend kangaroo care, non-nutritive sucking, and swaddling/facilitated tucking interventions, rocking/holding for reduction in both pain reactivity and immediate pain-related regulation that influences positive neurobehavioral states [13]. Bellieni, *et al*. [14] used sensorial saturation, a multi sensorial stimulation technique consisting of tactile, vestibular, gustative, olfactory, auditory and visual stimuli, as a means of analgesic tool for heel prick in preterm infants.

IMPLICATIONS FOR CLINICAL PRACTICE

The infants should be swaddled during the non-contact period with the mother and while sleeping; adverse tactile stimulation needs to be avoided during sleep cycles. Gentle touch, massage and kangaroo mother care (KMC) should be provided while the infant is alert and awake.

KINESTHETIC/PROPRIOCEPTIVE STIMULATION

Range of motion activities: The spontaneous movements of extremities are very much decreased in preterm very low birthweight infants because of hypotonia. Further, with swaddling and minimum handling requirement of infants in NICU, they are further deprived of physical activity. Moyer-Mileur, *et al*. [15] reported positive effects of range of motion activities and gentle longitudinal compression of extremities (passive weight bearing) on improved weight gain, bone width and bone mineral density. Similar observations were reported with evidence of increased circulating Leptin levels correlated with birth weight suggesting increased bone mineralization [16]. A systematic review concurs that there is some evidence that physical activity programs might promote short-term weight gain and bone mineralization in preterm infants but lacks evidence for long-term effects. The literatures in systematic review lacked methodological and reporting quality [17].

Infant positioning: The preterm infants have hypotonia that brings about difficulty in using the extremities in midline and sustaining the symmetrical flexion posture and movements. During NICU stay, such infants should be positioned in supine (in swaddled position) during sleep cycles; also in prone position for brief period when the infant is alert and awake. Infants positioned in prone are reported to have attained motor milestones much earlier than infants positioned in supine position. Prone positioning may also prevent positional deformational plagiocephaly, which may have some implications on neurodevelopmental behavior [18,19]. A transient delay

in motor development has been reported for healthy term and low-risk preterm infants who were not exposed to the prone position or who did not use infant equipment [20]. Infants positioned in supine, prone and side-lying maintained in tucked flexion respond with more spontaneous midline activities and symmetrical antigravity flexion postures, similar to that of full term infants [21].

IMPLICATIONS FOR CLINICAL PRACTICE

The range of motion activities should be combined with massage for improved weight gain. The infant should be positioned supine while sleeping; and in prone / side-lying while alert and awake for improved neuro-motor behavior.

OLFACTORY - GUSTATORY STIMULATION

The amniotic fluid that is being swallowed by the fetus facilitates early chemosensory experiences. During postnatal period these chemosensory experiences combined with sucking reflex activity facilitate nutrition seeking behavior and also the tactile needs of the infants (to feel relaxed and secured with the mother or to explore the environment around it). Preterm infants are not able to coordinate sucking, swallowing and breathing and hence will depend upon alternative feeding methods *viz*. tube feeding, cup feeding, syringe or dropper feeding, bottle feeding with expressed breast milk. These feeding methods deprive the preterm infant from normal sensory experiences of taste and smell. Further, the unpleasant and noxious odors arising from the hospital disinfectants, solutions, and antibacterial compounds can have a negative impact on already deprived smell and taste sensations. The extended duration of alternative feeding methods also has a negative impact on the sucking behavior of these preterm infants [22].

Non-nutritive sucking (NNS): Non-nutritive sucking involves sucking of the pacifier (physiologically designed nipples), the digit or the emptied breast. During gavage feedings and transition from gavage to breastfeeding, non-nutritive sucking should be encouraged as part of developmental care interventions. It facilitates the sucking behavior of infants and will also improve digestion of enteral feeds through secretion of specific digestive enzymes mediated by vagal innervations of oral mucosa [23]. A systematic review on the effect of non-nutritive suckling reports significant decrease in the length of hospital stay and no clinically significant changes in weight gain, energy intake, heart rate, oxygen saturation, intestinal transit time, age at full oral feeds and behavioral state [24]. It also identified positive clinical outcomes of NNS such as smooth transition from tube to bottle feeds and better bottle feeding performance. No negative outcomes were reported in any of the studies [24].

Oro-motor stimulation: Infants on longer duration of alternative feeding methods have greater difficulty in transition to breast feeding. A randomized controlled trial on Premature Infant Oral Motor Intervention (PIOMI) program reports improved transition and increased feeding tolerance from tube-feeding to breastfeeding and shorter duration of hospital stay. The five minute stimulation program involved assisted and resisted movements of oro-facial muscles; facilitated coordinated movement of cheeks, lips, gums, tongue and palate, and digital stroking of the same [25].

Nutritive sucking/Breastfeeding: Breastfeeding involves active sucking of the mother's breast by the infant. Human milk is the preferredexclusive nutrition to improve weight gain, immune status and cognitive development of the infant [26]. Breastfeeding allows maternal involvement in feeding and maternal confidence; facilitates mother-infant interaction, bonding and attachment pivotal for socio-emotional development of the infant. Exclusive breast feeding is part of the standard kangaroo mother care. The results of a systematic review indicate that optimal duration for exclusive breastfeeding should be at least six months and prolonged breast feeding durations does not have any beneficial effects on cognitive ability [27]. The results of two large independent population based cohorts of very preterm infants on breast feeding reports better neuro-developmental outcomes despite sub-optimal weight gain [28].

IMPLICATIONS FOR CLINICAL PRACTICE

During gavage feedings and transition from gavage to breast feeding, non-nutritive sucking should be combined with oro-motor stimulation for smooth and early transition to breastfeeding. Exclusive breastfeeding should be continued at least for six months.

VESTIBULAR STIMULATION

Positive effects of vestibular stimulation on arousal level, visual exploratory behavior, motor development and reflex integration have been reported in the literature [29].

AUDITORY STIMULATION

The fetal response to auditory stimuli (maternal voice) indicated by spontaneous movements is noted as early as 27 weeks of gestation that establishes social attachment and communication during early development. Exposure

to noise levels of greater intensities arising from various equipments in the NICU environment act as stressors to the preterm infants [30]. Darcy, *et al*. [31] in their descriptive study recommend behavioral and structural changes to abate increased sound levels in NICU. Behavioral changes involve staff sensitization on recommended noise levels and its impact on the infant; encouraging nurses to silence alarms promptly, using quieter alarms or lights, and encouraging conversation away from the bedside can all help decrease the noise level in a NICU. Structural changes to the NICU physical environment would serve as the long term strategy in noise abatement.

An expert review panel has recommended the need for a system of regular noise assessment, sound limit at 50 dB(A), development and maintenance program of noise control and abatement, improved parent-infant interaction through parental voices at the bedside, non-use of earphones and other devices attached to the infant's ears for sound transmission or routine / unattended use of recorded music or speech in the environment of the high-risk infant [32]. Similar findings have also been reported from a recent Indian study [33].

VISUAL STIMULATION

The visual system is the last among all the sensory modality to develop and the visual pathway matures only at the time of birth around 39 to 40 weeks. Visual experience for healthy visual development requires ambient light (not direct light); and, after 2 to 3 months, color. Thus the visual care interventions for preterm infants until 40 weeks corrected age will include exposure to rhythmic low level ambient lights for entrainment of circadian rhythm, prevention of eyes from direct light exposure, and facilitation of sleep cycles [34].

Cycled lightings in NICU as visual stimulation are used to establish circadian rhythms of rest-activity cycles in preterm infants. Infants who were exposed to diurnally-cycled lighting while in intensive care experienced both physical and behavioral developmental benefits; improved weight gain, early transition to oral feeding and shorter hospital stay [35]. A meta-analysis on cycled lighting effects on preterm infants in NICU reports a trend to improved weight gain, shorter length of hospital stay and less incidence of Retinopathy of Prematurity (ROP) when compared to near darkness or continuous bright light [36].

IMPLICATIONS FOR CLINICAL PRACTICE

The preterm infants should only be exposed to ambient and cycled lightings and not to direct / continuous bright light till 40 weeks corrected age.

MULTIMODAL SENSORY STIMULATION

Kangaroo Mother Care (KMC): The standard kangaroo mother care includes intermittent prolonged skin-to-skin contact of the infant with the mother and exclusive breast feeding. KMC provides tactile stimulation to the infant by having prolonged skin-to-skin contact with the mother; kinesthetic-proprioceptive stimulation by swaddled positioning of the infant; olfactory-gustatory stimulation by breastfeeding; oro-motor stimulation by sucking the nipple and auditory stimulation by the maternal voice. Skin-to-skin contact improves neurobehavioral organization and physiological states; prevents hypothermia in preterm infants as these high risk infants have poor thermoregulation. Further it improves infant-mother interaction, bonding and attachment essential for emotional and social development.

The clinical evidence of KMC on physiological states describes clinically acceptable and stable ranges of heart rate and respiratory rate than the incubator period; statistically significant increase in oxygen saturation levels compared to incubator values; significant reduction in desaturation levels as a result of KMC compared with swaddled holding; significant reduction in apnic spells when compared with incubator care; increase in body temperature and maintenance of thermal regulation; decreased levels of cortisol; statistically significant increase in weight gain; decrease in the incidence of nosocomial infections and improved blood glucose levels. The clinical evidence on neurobehavioral outcomes following KMC has shown improved sleep patterns and organization; decreased crying frequency; enhancement of breast feeding amongst preterm infants; increased alertness/attention and reduction in overall likelihood of neurodevelopmental delay. The psychosocial effects of KMC have shown to improve parental feelings and interactions with the infant. Early initiation of KMC, prolonged duration (continuous and overall intermittent duration) and frequent KMC intervention are reported to have more beneficial effects [37,38].

IMPLICATIONS FOR CLINICAL PRACTICE

Given the multi-sensory stimulation nature of KMC, it should be initiated at the earliest and should be continued at least for six months along with exclusive breastfeeding.

Other models of multi-modal sensory stimulation: White-Traut documented the positive effect of Auditory, Tactile, Vestibular and Visual (ATVV) intervention on increased alertness, faster transition to nipple-feeding, and decreased length of hospitalization. [39]. The study on

RISS (Rice Infant Sensory Stimulation) intervention, that combines talking, massage, eye contact and rocking, has reported to enhance mother-infant interaction [40]. Another intervention model, comprising of home-based early stimulation carried out by the mother has been reported to improve the developmental status of at-risk babies at 1 year [41].

CONCLUSIONS

The success of developmental care interventions, in NICU and beyond hospital stay, largely depends on the engagement of infant's mother and family in the intervention program. The Literature on Developmental Care Interventions mostly reports positive effects on neurodevelopmental outcomes, physiological and behavioral states. Since the components of Developmental Care Interventions are cost-effective and feasible, the interventions should be carried out to help the preterm infants cope with the environmental demands in NICU and beyond hospital stay. The structuring and designing of NICU environment for the high risk neonatal graduates has important policy implications for neonatal healthcare.

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