Seminars in Fetal and Neonatal Medicine 27 (2022) 101369

Contents lists available at ScienceDirect

Seminars in Fetal and Neonatal Medicine

journal homepage: www.elsevier.com/locate/siny

Nursing care of infants born extremely preterm

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ARTICLE INFO

Keywords:
Insensible water loss
Skin to skin care
Immaturity
Family integrated care

ABSTRACT

With improving survival at the lowest gestations an increasing number of tiny and vulnerable infants are being cared for, and optimal outcomes require an approach to care that takes their specific characteristics into account. These include immature organ function and a risk for iatrogenic injury, and parental/familial strain due to the high degree of uncertainty, infant-mother separation, and long hospital stay. While the challenges in providing nursing care to these infants are obvious it is also clear that this field has tremendous potential to influence both short and long-term outcomes of this population. This mini-review discusses aspects of the nursing care provided to infants born at the very lowest gestations and their families, with focus on doing less harm by establishing an adequate care environment, actively promoting parental closeness and care-giving, and conservative skin care.

1. Introduction

At the lowest gestations an increasing proportion of mother-infant dyads are receiving care aiming at optimal outcomes [1–3], and several institutions consistently report survival of more than 50% of live born infants, even at 22 weeks of gestation [4–7].

While the challenges in providing care for these tiny vulnerable infants, and their families is obvious, knowledge obtained from high-quality trials is entirely lacking in this population, thus limiting the possibility of establishing an evidence-base from which management can evolve and be fine-tuned to the specific needs of the individual patient. Consequently practices differ significantly even among centers with similar (and reasonably good) outcomes [8] and the best outcomes to date most likely result from an ill-defined combination of attitude, dedication, and experience [9]. Such experience thus rely mostly on regimens locally developed over time, partly by extrapolating from slightly larger and more mature infants. The particular nursing aspects of the care provided to these infants are closely intertwined with the medical treatments and procedures, and details in bedside nursing most likely impact outcomes at least as much as the medical management. Numerous examples demonstrate how quality improvement initiatives in nursing routines (e.g. management of iv. lines) have resulted in impressive gains in quality of care (reduced rates of late onset sepsis), and outcomes. The aim of this mini-review was to highlight important areas of the nursing management that the authors consider critical to the care of infants of extremely low gestational age.

1.1. Family integrated care (FICare)

1.1.1. Parental involvement, non-restricted access, and shared decision-making

It is well described that preterm birth and/or the subsequent hospital stay [10] as well as the physical separation from the infant evoke stress and anxiety in parents, and experimental data indicates that the separation *per se* is stressful also for the infant [11].

The concept of a family centered/integrated care [12] aims to promote skin-to-skin care, involve parents in decision-making, and provide education and psychological support. By its focus on establishing the parents as their infant's primary caregiver [13], FICare involves parents starting from birth/admission to discharge, and beyond. Parents are trusted with care tasks such as taking selected vital parameters, tube feeding, changing diapers etc., which together with a wide range of actions from minimizing painful procedures to the exclusive provision of breast milk, serves to support a "healing" environment [14]. Key to the concept is to avoid separating the mother/father from their newborn and every effort is made to establish skin-to-skin contact as early as possible, ideally in the delivery room [15]. While the NICU staff takes on a supervising and supporting role, they retain medical responsibility and oversight. The staff as well as the physical environment/design of the NICU has a pivotal role to allow and encourage parents to take active part in their infants' care. As an example it has been demonstrated that having a parental bed next to each infant's care space was associated with the parents spending more time (and earlier) bedside as compared to when the care spaces were equipped with an armchair [16]. Other

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https://doi.org/10.1016/j.siny.2022.101369

Available online 18 June 2022

"signals" such as visitation policy are also important to encourage parental involvement [17]. Parents should be included in all relevant decision making regarding their infant, including participation in medical rounds, staff hand-overs, and care planning meetings [18].

Studies indicate that FICare can improve infant weight gain and breastfeeding rates, reduce parental stress/anxiety and length of stay, as well as the rates of nosocomial infections and re-hospitalization [19].

1.2. The infant-environmental interphase

1.2.1. Skin barrier function and insensible water loss (IWL)

The barrier properties of the epidermis depends on the integrity of the stratum corneum and while a thin (a few microns) keratin layer forms at 20–24 weeks gestation [20], it is still largely non-functional [21]. On the other hand, the skin structure of a 30-week fetus share several more similarities with the competent while yet delicate skin of an infant born at term. In parallel, across these gestational ages skin barrier function ranges from almost entirely deficient to close to competent, which has important clinical implications. Firstly, the rate of which water is lost through the skin is inversely related to gestational age at birth, with resulting much higher IWL in a 22-week gestation neonate than in an infant born only a few weeks more mature [22]. Secondly, the absence of barrier competency and resilience poses a significant risk for percutaneous absorption of hazardous substances, microbial invasion, further barrier disruption, and pain or discomfort [23].

Fortunately, the immature skin responds when being exposed to the relatively dry extrauterine environment. In parallel to what occurs with any barrier disruption (e.g. skin abrasion/wound), the increase in transepidermal water flux is the key signal for epidermal proliferation, and subsequent keratinization [24]. A few days after extremely preterm birth this hyper-proliferation often gives the skin a scaly and crackling appearance, by many referred to as "skin breakdown", sometimes prompting myriads of unproven treatments. However, this is partly a misnomer since this proliferative process is paralleled by an improvement of barrier function that is more rapid than the developmental fetal skin formation *in utero* [22]. In fact, in extremely preterm infants IWL will be reduced by as much as 30–50% by one week of age [21].

1.2.2. IWL in relation to ambient relative humidity (RH)

The magnitude of water loss from the skin is inversely proportional to the vapor pressure of the microenvironment close to the surface. This relationship has been documented in newborn infants with direct measurements of evaporation [21] as well as in studies where IWL was estimated from data on fluid intake, weight change and urine output [25], showing that IWL can be managed by use of incubator humidification. The addition of vapor to the ambient air of modern neonatal intensive care incubators to high levels of RH (>80%), results in an IWL that corresponds to that of a 3–4 weeks more mature infant nursed at medium RH (40–50%), thus reducing fluid requirements and simplifying management. Since evaporation also implies loss of heat, humidifying the incubator air also reduces heat loss as long as the care environment remains unperturbed [26].

1.3. Routes of heat exchange and choice of care environment

Heat exchange between the infant and its environment occurs mainly through the skin while losses via respiration are negligible with the use of heated/humidified gas. A basic understanding of the four modes of heat exchange (convection, radiation, conduction, and radiation) makes it straightforward to tailor the care environment to the unique needs of the different clinical situations encountered in the care of extremely preterm infants.

The general features of the different care modalities and their suggested use are presented in Table 1. For initial (delivery room) management the advantages of using a radiant warmer bed are obvious since heat loss from the wet skin surface can rapidly result in hypothermia. By immediately placing the infant in a plastic bag (convective and evaporative heat loss reduced) on the mothers chest (conductive gain) or under a radiant warmer (radiative gain), hypothermia can be avoided [27]. After NICU admission and for placement of umbilical catheters, X-ray etc., care under a radiant warmer or in a closed incubator are reasonable options.

Although it might seem wise to always care for the tiniest infants at a high RH by exclusive use of humidified closed incubators, closed incubators are often impractical due to limited access for both parents and staff, and poor visibility caused by incubator hood "rain-out" have been associated with microbial growth. If there is a frequent need for nursing procedures leading to perturbation of the care environment and subsequent thermal instability, radiant warmers might indeed be a better choice and has been proven to allow fluid homeostasis for this group of infants [6,28]. Further, results obtained in extremely preterm infants [29] imply that the skin barrier forms more rapidly at lower ambient RHs. With increasing postnatal age and thermal stability, humidification can be reduced and care outside the incubator/radiant warmer promoted. A suggested timeline for adjusting incubator humidification and initiation of skin to skin care is presented in Fig. 1.

1.4. Temperature monitoring

Rectal temperature do not reliably reflect core temperature, are associated with discomfort and risks of trauma to the rectal mucosa, and

Table 1
Care environment and heat exchange in extremely preterm infants.

When?	Use	Why?	Note!
Delivery room	Plastic bag	Convective heat loss ↓ Evaporative heat loss ↓	Keep bag until body temp stable after procedures.
	RW	Radiative heat gain ↑	Avoid over-warming!
NICU (1st week)	RW	Radiative heat gain ↑	Use Saran wrap or similar to reduce convection Use Saran wrap or similar to reduce convectionFluid requirements ↑ vs incubator
	Incubator (80+% RH)	Convective heat gain ↑ Evaporative heat loss ↓	Avoid incubator wall "rain-out"
	SSC	Optimal thermal stability Low infant stress Parental empowerment	Delay for a few days in the most immature; duration >2 h.
NICU (2nd week)	SSC		In most cases unrestricted.
	RW		Excellent access.
	Incubator (50% RH)		High RH's can be weaned.

DR, Delivery room; SSC, Skin-to-skin; RW, Radiant warmer; RH, Relative humidity.

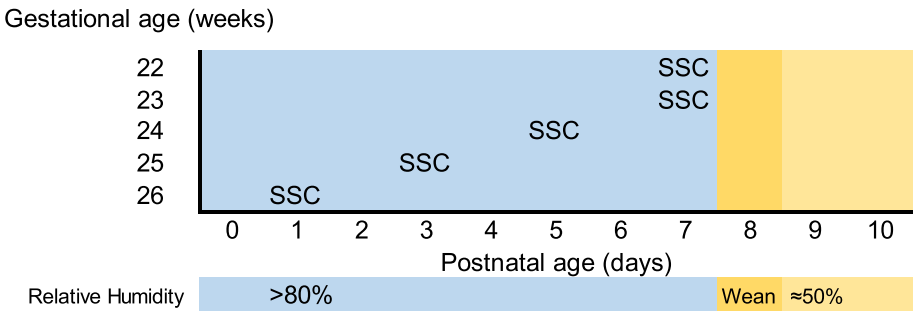

Fig. 1. Suggested timeline for weaning of incubator humidification, and initiation of skin-to-skin care (SSC).

should not be used. A combined feeding tube and thermometer is a near-optimal solution for reliable monitoring of body temperature (and servo-control of heat delivery) and should be readily available and spread in the neonatal care community.

Body temperature can also be estimated from measurements at the body surface. By insulation of the measurement probe, "zero-heat-flux" is created between the body core and the probe, and thus enables estimation of central body temperature. Trunk skin temperature measurements (back to mattress, or abdomen to insulated pad) rely on this principle and give readings that are very similar to core. Axillary temperature also makes use of zero-heat-flux (insulated by the arm/shoulder) and can be used as a proxy for core temperature when intermittent measurement is deemed sufficient but is associated with infant discomfort and occasionally differ from esophageal temperature.

Although the normal range of central body temperature of 36.5–37.5 °C, is considered valid also for the preterm infant, it is evident that a proportion of infants temperatures in this range may still be experiencing cold stress (i.e., have an increased metabolic rate due to thermogenesis). Thus, in parallel with the fetal thermal equilibrium, and in order to minimize the risk of cold stress, it is adequate to aim for slightly higher core temperatures in infants born preterm. Table 2 displays suggested target temperatures and ranges of normal body temperatures in extremely preterm infants.

1.5. Nursing care recommendations

1.5.1. Minimize pain and stress

Exposure to pain and stress is greatest in the first 14 days of life, and in the most immature infants, and has been associated with suboptimal brain growth, and poorer long-term neurodevelopment [30].

Considering the huge load of sensory stimuli that these infants experience during a highly vulnerable time period in development, initiatives seeking to characterize and develop a less harmful environment [31] could intuitively be expected to have positive effects, although clear evidence for its benefit is lacking [32]. Further, from a humane standpoint there are obvious reasons that every effort should be made to reduce noxious stimuli and environmental stress by adapting the environment and challenging the indications for existing routines regarding care intervals, procedures, blood sampling, etc. [33].

Table 2
Body temperature targets in extremely preterm infants.

Heat mode	Monitoring	Target	Note!
Servo	Insulated skin probe (abdomen)	37.0 °C (week 1-2); 36.5 °C (week 3-4)	Adhesive pad, Rarely used > 2nd week
	Esophageal probe	37.0 °C	In OG tube
Manual	Insulated skin probe (back) Axillary	36.7 °C- 36.7–38.2 °C	For 1st week SSC

OG, Oro-gastric; SSC, Skin-to-skin care.

1.5.2. Care planning, handling and positioning

Even minor routine caregiving procedures such as diaper changes are associated with cerebral circulatory fluctuations [34], and cardiovascular instability [35], particularly in combination with sleep disruption [36]. Grouping of care activities around a single caregiving event has been suggested to promote neurodevelopment [37], by allowing longer periods of undisturbed rest/sleep [36].

On the other hand such "bundling" of complex caregiving seems to impose a higher magnitude of hemodynamic changes [34,35], and thus has to be halted if the infant show signs of stress/instability. In our experience an interval between cares of 4–6 h is a reasonable compromise between the need for diaper changes, body positioning and monitoring. Vital signs can be taken visually in most clinical situations.

Many centers have implemented "IVH prevention-bundles" [38] to reduce the risk of intraventricular hemorrhage during the first days of life. These almost universally includes strict positioning of the head in midline, although firm data to support this practice are lacking [39]. There is however, some support for flexed positioning of the infant in a nest (Fig. 2) [40], and that caregiving should be provided by two persons so that one, ideally a parent, can provide comfort and positioning [41].

1.5.3. Skin care

Nurses caring for extremely preterm infants report adhesive-related skin injuries, friction injury, pressure site injury, perineal skin breakdown, chemical burns from use of antiseptic solutions, and diaper dermatitis [42].

Although the evidence is weak or inconclusive regarding how to best avoid, and manage such injuries, a few reasonably well founded

Fig. 2. A 23 week gestation infant resting calmly on day of life 4. Note the optimal flexed position supported by a nest with hands tucked close to the face/mouth, and eyes covered during phototherapy. The skin appears intact and no ECG-leads or other adhesive probes are used (monitoring by oximeter and indwelling blood pressure curve).

recommendations can be made:

1.5.4. Adhesive use

- Adhesives and their removal has the potential risk to strip the skin and their use should be minimized, and when necessary, silicone adhesive seems to strip the skin less than acrylate [43].
- Adhesive removal should be gentle and by pulling on a horizontal plane, after wetting the adhesive. Adhesive removers (mineral/petrolatum oil, or silicone-based) in wipes are convenient and reduce adhesion instantly [42]. However, their safety has not been evaluated and very restrictive use is advised during the first 1–2 weeks after birth.
- Silicone- and hydrocolloid-based dressings can preferably be used beneath tapes to avoid pressure trauma from e.g. endotracheal and nasogastric tubes.
- Polyurethane adhesives, such as in transparent dressings, has the benefit to be non-occlusive (permeable) and allow inspection of the underlying skin.

1.5.5. Wound management

Should an injury occur, evidence support conservative management with saline cleansing and dry care. Antiseptic skin cleansing solutions delay skin healing and are probably best avoided, at least unless there are signs of infection [44]. Topical emollients are widely popular in neonatal care but their benefit for extremely preterm infants has not been proven [45].

1.5.6. Skin disinfection

For skin disinfection prior to insertion of vascular accesses there is evidence to support the use of 2% chlorhexidine gluconate instead of 0.5% chlorhexidine gluconate in 70% alcohol, as it is associated with fewer skin lesions and similar rates of central-line associated bloodstream infections [46,47].

1.6. Skin-to-skin care

Consensus prevails regarding skin-to-skin care (SSC) as the optimal environment for any newborn, and for the preterm in particular. In the extremely preterm infant however, many argue that SSC should be restricted early in life due to a perceived increased risk for IVH [38], but to date no study has addressed this specifically. Clearly, there are challenges when introducing SSC in the first days of life but the studies available support the notion that SSC can be safely introduced toward the end of the first week also in the tiniest of infants and that normal body temperature can be maintained [48,49]. We have previously proposed a standardized SSC-method for the transfer from the incubator, infant position and cover, and a minimum duration of 2 h [50]. From the second week of life thermal homeostasis is easier to achieve (authors' unpublished data) and SSC should from then onwards in most cases be unrestricted.

1.7. Agenda for nursing research and quality improvement

After birth the extremely preterm infant is exposed to stimuli that differ entirely in quality and intensity from those in the womb, and maturation, development, and growth must now take place in an intensive care unit setting. Optimal outcomes require the establishment of standardized nursing protocols integrated with the medical management, and designed to minimize harm and encourage parental involvement. It is our experience that every detail in the nursing procedures need to be carefully tailored and taught to dedicated staff, in order to reduce the number of interventions and cares. While sound and non-invasive methods such as skin-to-skin care are likely to be beneficial also to the extremely preterm infant, best practice has not been clearly defined and questions remain regarding timing, positioning, care space organization, and staff ergonomics. Further, knowledge is lacking on how to best care/treat the immature skin to promote barrier integrity, but while awaiting evidence from clinical trials, a conservative attitude towards skin ointments/dressings, and adhesive removers, seems reasonable. Since randomized controlled trials investigating each aspect of the nursing care are not easily conceptualized in this relatively small population, the sharing of experiences and comparison of care approaches between centers could be expected to yield valuable insight and significantly contribute to improved infant outcomes.

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