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Medical Adhesives in the NICU

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ABSTRACT

Skin injury from medical adhesives is a known problem for neonatal intensive care unit (NICU) patients. Medical adhesive-related skin injury (MARSI) for all patient populations includes mechanical problems such as skin stripping, skin tears, and tension blisters; dermatitis reactions such as irritant contact dermatitis and allergic dermatitis; and other complications such as skin maceration and folliculitis. The most common seen in neonatal patients is epidermal or skin stripping; chronically hospitalized infants may also experience irritant contact dermatitis to a variety of adhesive products. Preventing MARSI is the goal, using the fewest and least irritating adhesive products; yet, secure fixation of medical life support equipment is imperative. This article will explore differences in neonatal skin that place NICU patients at risk for MARSI and selecting products that are most appropriate for the desired result. Barrier films and adhesive removers are also discussed in detail to determine which may be potentially beneficial to the NICU population.

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Medical adhesives comprise an integral part of healthcare delivery in the Neonatal Intensive Care Unit (NICU) and in virtually all other inpatient and outpatient settings, as a component of a variety of products, including tapes, dressings, electrodes and ostomy supplies. Medical adhesives are applied and removed many times a day in the typical NICU. Premature and full-term infants who require medical interventions and constant monitoring are exposed to adhesives for a wide variety of indications. They secure both critical life support equipment such as endotracheal tubes, intravenous and arterial catheters, and chest tubes, as well as monitoring devices such as electrocardiogram electrodes, pulse oximeter probes and temperature sensors.

Skin injury from medical adhesives is a known problem among healthcare providers in the NICU. In the 2001 evidence-based practice project conducted in 51 US nurseries involving 2820 premature and term neonates, adhesives were the primary cause of the observed skin breakdown.[1] A descriptive cohort study conducted in Australia found the incidence of "pressure injuries" (which is a broader category of iatrogenic tissue damage that includes epithelial stripping) in 247 neonates to be 31.2%; medical devices were the most common risk factor associated with the skin injuries.[2]

In the broader pediatric population, a 1-day prevalence audit reported that 8% of hospitalized infants and children were found to have tape-related skin stripping,[3] and the 2003 National Pediatric Pressure Ulcer and Skin Breakdown Prevalence Survey found that the prevalence of skin stripping related to adhesive tape was 17%.[4] Because of these studies and a general concern in all populations of hospitalized patients, the acronym "MARSI" was coined, standing for "medical adhesive-related skin injury".[5]

In an effort to increase awareness of MARSI and define best practices for prevention of this skin injury, a consensus panel of 22 health care providers from a variety of disciplines (nursing, medicine, physical therapy) and specialties (neonatology, pediatrics, geriatrics, orthopedics, dermatology, infusion nursing, infectious disease) convened to establish consensus statements on the assessment, prevention, and treatment of MARSI. Additional goals included defining knowledge gaps regarding medical adhesives and skin safety, documenting the spectrum of care settings and medical applications where MARSI occurs, and identifying research priorities for development of new adhesive technologies and protocols for skin protection. Following this meeting, a white paper was published with the 25 consensus statements reached by the group.[5]

This paper will explore the unique differences in newborn skin that place NICU patients at high risk for MARSI, and the types of MARSI seen in this population. Following this, background on the science of medical adhesives and how adhesives interact with the skin, and the types of adhesives and adhesive products commonly used in the NICU is described. In addition, products that protect skin from adhesive damage or facilitate removal of adhesives without injury to the skin will be discussed.

Physiologic and Anatomic Variations in Newborn, Premature, and Infant Skin

Stratum Corneum and Epidermis

The stratum corneum, which provides the important barrier function of the skin, contains 10 to 20 layers in the adult and in the full term newborn. Although full term newborns have been shown to have skin barrier function comparable to adult skin[6] using a measurement called transepidermal water loss (TEWL), there is now some evidence that the stratum corneum does not function as well as adult skin throughout the first year of life[7] and is 30% thinner than that of

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adult skin.[8] Directly underneath the stratum corneum, the basal layer of the epidermis is 20% thinner than that of the adult, and the keratinocyte cells in this layer have a higher cell turnover rate which may account for the faster wound healing that has been observed in neonates.

The premature infant has far fewer layers of stratum corneum, and is determined by their gestational age. At less than 30 weeks gestation, there may be as few as two or three layers,[9] and the extremely premature infant of 23 to 24 weeks has negligible barrier function due to minimal stratum corneum.[10] Because of the deficiency in layers of stratum corneum, large fluid and evaporative heat losses can occur in the first weeks of life, leading to significant alterations in electrolyte levels, hypernatremia and dehydration.[11] Techniques used to reduce these losses include the use of polyethylene coverings immediately after delivery,[12–14] and use of high levels of relative humidity (>70% RH) in incubators.[15,16] Topical treatments such as the application of transparent adhesive dressings,[17,18] and sterile topical ointment and skin protectants have been described in small studies,[19,20] but remain controversial due to concerns for infection.[21] The process of maturation of the skin barrier, particularly for infants of 23 to 25 weeks gestation occurs over time,[10,22] with measurements of mature barrier function found as they reach 30–32 weeks postconceptional age.[23]

Dermis

The dermis of the full-term newborn is thinner and not as well developed compared to the adult dermis. The collagen and elastin fibers are shorter and less dense, and the reticular layer of the dermis is absent, which makes the skin feel so soft. There are less total lipids and fewer sebaceous glands in the dermal layer in infancy.[8]

Cohesion Between Epidermis and Dermis

The junction between epidermis and dermis contains fibrils that connect these two layers of the skin. In premature infants, the fibrils are fewer in number, with wide spaces between connecting points.[9] As the premature infant becomes more mature these fibrils increase in number and strength. Abnormal fibrils at the junction of the epidermis and dermis are found in certain types of the genetic skin disease, epidermolysis bullosa, a blistering skin condition that occurs with even minimal trauma to the skin.

This decreased cohesion between epidermis and dermis places the premature newborn at risk for skin injury from removal of medical adhesives that are attached to the skin. When extremely aggressive adhesives are used, the bond between adhesive and epidermis may be stronger than that between epidermis and dermis, resulting in stripping of the epidermal layer and decreased skin barrier function.[24]

Risk of Toxicity from Topical Agents

Toxicity from topically applied substances has been reported in numerous case reports due to the increased permeability of both preterm and full term newborn skin. This is due to a number of factors including the fact that newborn skin is 20%–40% thinner than adult skin, and the ratio of body surface to weight is nearly five times greater than older children and adults, placing them at increased risk of percutaneous absorption and potential. Examples of toxicity from percutaneous absorption include hexachlorophene bathing leading to encephalopathy and death in premature infants, and thyroid toxicity from povidone–iodine used for skin disinfection toxicity.[25,26] Thus, using topical agents carries a risk should they be absorbed through the skin of the premature or term neonate.

Other Challenges in the NICU with Medical Adhesives

The skin of a normal term infant is covered with vernix caseosa, a "cheesy" substance composed of water (80%), lipids and proteins,[27] sebum from sebaceous glands, broken-off lanugo, and desquamated cells from the amnion. Vernix production begins at the end of the second trimester protecting the fetal skin against maceration from amniotic fluid and chafing caused by crowding in utero. Leaving residual vernix intact may be beneficial after delivery as it assists in the formation of the acid mantle, facilitates colonization by normal bacterial flora, and serves as a natural moisturizer for the skin;[28–30] it also makes adherence of medical adhesives very difficult. Some manufacturers of electrocardiogram (EKG) electrodes, for example, recommend preparing the skin surface with isopropyl alcohol to improve adherence, but this practice is very irritating to the skin.

Another factor complicating the application and removal of medical adhesive products is the use of thermoregulation devices. Radiant warming tables and convectively heated incubators are necessary for most neonates admitted to the NICU during initial stabilization and for premature infants for many days, weeks or months; the use of high ambient humidity levels (>70%) in incubators is often employed in the care of extremely low birth weight prematures (<28–30 weeks gestation) during the first weeks of life to mitigate the excessive transepidermal water loss and evaporative heat loss that occurs due to their undeveloped stratum corneum. These thermal management techniques and devices may cause instability of many adhesive products, resulting in adhesives inadvertently falling off. Radiant heat from warming tables can also cause some adhesives to attach more firmly.

An additional concern is the population of NICU patients with chronic illnesses such as complex congenital heart disease, short bowel syndrome, bronchopulmonary dysplasia or other conditions that necessitate their remaining hospitalized for many, many months, often with oxygen cannulas, feeding tubes, central venous catheters and other adhesive products in use. In this population, an increase in contact dermatitis in response to a variety of adhesive products is being observed, challenging the clinician to find alternative adhesive products that the infant does not react to in this way.

Medical Adhesives and Medical Adhesive Products

The US Food and Drug Administration (FDA) defines a medical adhesive tape or adhesive bandage as "a device intended for medical purposes that consists of a strip of fabric material or plastic, coated on one side with an adhesive, and may include a pad of surgical dressing without a disinfectant. The device is used to cover and protect wounds, to hold together the skin edges of a wound, to support an injured part of the body, or to secure objects to the skin".[31]

Medical adhesive tapes/dressings/devices are composed of several layers. The type of backing and adhesive used determines the properties and performance of the adhesive product. For example, tape backings can be composed of paper or paper blends, plastic, silk (woven polyester), soft (non-woven) cloth, traditional cloth, or foam and/or elastic. Examples of types of adhesives used in tapes and dressings include acrylates, silicones, hydrogels, hydrocolloids, and polyurethanes, as well as those that are natural-rubber latex based or contain zinc oxide (Table 1).[5,32,33]

Medical adhesives are pressure sensitive; firm pressure applied to the surface of the medical tape/dressing/device will "activate" the adhesive by increasing the surface area contact. Over time, the adhesive will warm and flow to "fill in" the gaps between the adhesive and the irregularities in the skin surface, increasing the strength of the bond. The length of time for this process differs among different types of adhesive products. Some "softer" adhesives, such as silicone, have a lower surface tension and fill in these gaps quickly and maintain the same level of adherence over time. Others adhesives, such as the acrylates, act more slowly, and adherence increases over time to a state of maximal adherence, and then gradually the bond weakens. This is why, whenever possible, leaving an adhesive in place even when not in use, can assist in the removal process when the adhesive bond starts to lessen.

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