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Hospital-acquired skin lesions in the neonatal intensive care unit: A retrospective analysis of temporal trends and quality improvement strategies

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ABSTRACT

Purpose: Skin lesions in neonatal population are an emerging problem deserving attention from health care professionals. The purpose of this study is to retrospectively assess the incidence of hospital-acquired skin lesions during a 6-year period and to describe the characteristics of infants who developed them.
Design and methods: This was a retrospective observational study conducted in a university-tertiary care center between 2015 and 2020. A descriptive analysis of the observed skin lesions is presented according to 2 time periods: 1) the implementation phase of a quality improvement program (2015–2019) and 2) the postimplementation phase (2020).
Results: Our findings showed an apparent increase in the incidence of all reported skin lesions throughout the study period. Pressure injuries were the most frequently reported skin lesions showing an increasing incidence over time which, however, was paralleled by a reduction in their severity. Among pressure injuries, device-related injuries were the most commonly observed (56.6% and 62.5% in the two periods, respectively) with nasal continuous positive airway pressure-related injuries accounting for 71.7% and 56.0% of lesions, respectively, and mainly affecting the nose root. The occipital area was the most frequently involved site in cases of conventional pressure injuries.
Conclusion: Infants admitted to Neonatal Intensive Care Units may be at high risk of developing skin lesions. The adoption of appropriate preventative as well as treatment interventions could be effective in reducing the severity of pressure injuries.
Practice implications: The implementation of quality improvement strategies may contribute to prevent skin injuries or lead to their early detection.

Introduction

Skin integrity represents one of the main outcome indicators of nursing care quality. Alterations in skin integrity play a crucial role by opening a "gateway" to infections and thus exposing infants to potentially serious complications as well as increasing mortality (Noonan et al., 2006).

The occurrence of a skin lesion is associated with the following potential short- and long-term consequences: i) systemic absorption of topic medications used to treat the skin lesion; ii) pain exposure related to the healing process of a pressure injury with a possible impact on that may alter sleep-wake rhythms with a negative impact on later neurobehavioral development; and iii) a longer hospital stay (García-Molina et al., 2018).

However, the occurrence of skin lesions may be prevented if appropriate interventions are introduced in clinical practice when taking care of acute pediatric patients (Kriesberg Lange et al., 2018; Kulik et al., 2018; Peterson et al., 2015).

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Until a few years ago, infants were not considered at risk of developing pressure injuries (García-Molina et al., 2017). More recently, it has become evident that among pediatric patients, immobilized and critically ill infants admitted to high-intensity care units, such as neonatal and pediatric intensive care units (NICUs and PICUs), are more likely to develop assistance-related pressure injuries than those admitted to general pediatric units (Kriesberg Lange et al., 2018; Kulik et al., 2018; Peterson et al., 2015).

In particular, infants are at high risk because of skin immaturity, compromised perfusion, decreased mobility, neurological alterations, fluid retention and the need for medical devices (Visscher & Taylor, 2014).

Therapeutic medical devices account for 50–90% of neonatal pressure injuries and are mainly represented by endotracheal tubes and devices for noninvasive ventilation. Several neonatal risk factors may contribute to the development of pressure injuries: low birth weight (<2500 g), prematurity (<37 weeks of gestational age), systemic hypotension, hypothermia, and NICU hospitalization (García-Molina et al., 2017). Moreover, specific intrinsic risk factors are represented by the higher relative head volume and the characteristics of infants' skin, which has anatomical and physiological properties different from those of older children and adults (García-Molina et al., 2018).

In the neonatal population, skin lesions might be categorized as pressure injuries, tear injuries, extravasations, chemical burns due to drugs or alcohol-based disinfectants, medical device burns and diaper dermatitis (Meszes et al., 2017; Noonan et al., 2006).

The most frequent sites where pressure injuries may occur are the occipital region, fingers and feet (generally for the presence of the pulse oximeter), skin areas where catheters are placed and fixed, thorax (due to monitoring electrodes), ear lobes (due to capnometer), columella, back of the neck, nares and cheeks (because of nasal prongs and nasal masks used for continuous positive airway pressure) (García-Molina et al., 2017).

Furthermore, pressure injuries can be divided into conventional pressure injuries (caused by the body pressure on a bony prominence) or device-related pressure injuries (caused by the pressure of a medical device on tissues) (Visscher & Taylor, 2014). In infants, the occiput is the most frequent site where neonatal conventional pressure injuries occur because of the large bony area, and this kind of lesion may result in permanent alopecia and alteration of the body image, as well as pain, discomfort and psychosocial alterations (Kriesberg Lange et al., 2018). Instead, device-related pressure injuries are usually located at the nose because of noninvasive ventilation (Kriesberg Lange et al., 2018), and they can also lead to late presenting nasal deformities with cosmetic and functional sequelae (Imbulana et al., 2018; Li et al., 2015).

Overall, a prevalence ranging from 9.3% to 43.1% for all types of neonatal skin lesions has been reported (August et al., 2018), while the incidence of pressure injuries in neonates admitted to NICUs ranges from 3.7% to 21.6% (García-Molina et al., 2017); diaper dermatitis among hospitalized infants and children is quite common, with a reported prevalence of 17% to 43% (Merrill, 2015).

More recently, the European Pressure Ulcer Advisory Panel (EPUAP) has adopted the National Pressure Injury Advisory Panel (NPIAP) model, which is a clinical practice guideline for pressure injury prevention and treatment (Edsberg et al., 2016).

The NPIAP model classifies skin lesions based on the depth and severity of tissue injury (stage 1, 2, 3, 4 and unstageable) and on the color of the lesion. Moreover, the NPIAP/EPUAP's update in 2016 introduced the definition of "medical device related pressure injuries" that "result from the use of devices designed and applied for diagnostic or therapeutic purposes. The resultant pressure injury generally conforms to the pattern or shape of the device. The injury should be staged using the staging system" (Edsberg et al., 2016).

Most of the pressure injuries' preventative interventions in pediatric patients derived from studies based on adults (Kulik et al., 2018). With the increasing attention on the quality of care and on the patient's safety in neonatology, the development of hospital-acquired pressure injuries was analyzed, and appropriate strategies to prevent lesions in patients with different characteristics were warranted (Kulik et al., 2018).

A standardization of preventative and therapeutic strategies is important to reduce the risk of developing skin lesions, avoid unnecessary pain, reduce treatment costs, and individualize assistance to hospitalized infants based on their risk factors. All the nursing staff should know and follow the preventative strategies and treatments of lesions according to their own local protocol (Noonan et al., 2006). The benefits of standardized care include early risk identification and better adherence to evidence-based preventative interventions (Kriesberg Lange et al., 2018).

Therefore, skin care is one of the main interventions that health care professionals should manage when taking care of critically ill infants, particularly those with unstable conditions, as they are more likely to develop pressure injuries (García-Molina et al., 2017).

Hence, the aim of this study was 1) to retrospectively assess the incidence of skin lesions in infants admitted to the NICU during a 6-year period and 2) to describe the role of infant characteristics on the occurrence and type of skin lesions.

Methods

Study design and setting

This is a monocentric retrospective study conducted in the NICU of a university-tertiary care center in Milan that admits approximately 900 infants per year, with 23 beds for critically ill and preterm infants and 33 beds for those requiring special care.

After approval by the local Ethics Committee (Area 2 Milan), we retrospectively reviewed the dataset in which the nursing staff recorded the occurrence of skin lesions in a cohort of infants admitted to the NICU between January 2015 and December 2020.

A quality improvement project and a hospital-based education program on acquired pressure injuries' prevention have been carried out since 2015. Therefore, the study time was divided into 2 time periods: 1) the implementation phase (2015–2019) and 2) the postimplementation phase (2020).

Quality improvement and education process

The main steps of the quality improvement and educational programs are described in Supplement 1 (see supplementary material).

Implementation phase (2015–2019)

Different implementation and educational initiatives took place throughout this period.

In 2015, a few nurses started a training path on skin lesion prevention, supported by the wound care consultant of the institute. Afterward, a nursing group dedicated to pressure-skin lesions was established, and an electronic dataset was created to record the occurrence of skin lesions. To raise awareness regarding skin care and pressure injuries among the whole nursing staff, several educational meetings followed by a specific educational and training program were carried out by the initiative team together with the wound care consultant. At the end of this process, the dedicated nursing team acquired adequate expertise to autonomously manage skin lesions.

A local procedure on skin lesions was elaborated, which included preventative interventions, such as risk assessment, skin care (hygiene and hydration), nutritional condition control, and pressure injury management (devices, postural change).

New preventative and treatment strategies were introduced into clinical practice, such as the use of a special surface for pressure management to reduce and prevent conventional pressure injuries in the occipital area and platelet gel treatment for persistent, severe and difficult-to-treat pressure injuries. Research projects on the prevention

of device-related (especially nasal continuous positive airway pressure-related, NCPAP-related) and occipital pressure injuries were designed.

Postimplementation phase (2020)

This period was defined by a structured recording of all skin lesions in the dedicated dataset together with full application of the implemented local procedure, including preventive and treatment strategies. During this period, the occurrence of diaper dermatitis was also recorded in the dataset.

Outcome measures

Our primary outcome was the incidence of skin lesions based on the events recorded in the dedicated dataset. Skin lesions were classified according to the type and severity.

Skin lesions were subdivided into three categories according to the type: 1) device-related pressure injuries, including lesions caused by NCPAP (prongs and masks), endotracheal tube, humidified high flow nasal cannula (HHFNC), intravenous catheter, Electrocardiogram (EKG) and Electroencephalography (EEG) electrodes, temperature probes and tracheostomy cannula; 2) conventional pressure injuries; 3) other skin lesions, defined as nonpressure injuries (which included tear injuries, extravasations, chemical or medical-device burns, other skin lesions).

The severity of the lesion was defined according to the NPIAP for the staging of pressure injuries (device-related and conventional injuries). This staging system is based on the depth and severity of tissue injury, which is categorized as follows: stage 1, 2, 3, 4 and unstageable (Edsberg et al., 2016).

During the postimplementation period, a fourth category (diaper dermatitis) was recorded and analyzed separately. Diaper dermatitis is a cutaneous condition of the infants' diaper area where an acute inflammatory eruption of the skin is assessed. It involves the inner surface of the thighs, buttocks, abdomen and the surface of genital areas (Merrill, 2015).

The recorded data covered the presence of diaper dermatitis in infants admitted into the NICU and the infants' characteristics.

Infant characteristics

The infants' baseline characteristics were collected from the electronic medical charts and recorded in a dedicated electronic dataset for statistical analysis in a fully anonymized way, in accordance with the Good Clinical Practice guidelines. The recorded data included gestational age at birth (week), birth weight (g), sex, days of life and body weight at the occurrence of skin lesions, and days on noninvasive ventilation before the onset of skin pressure injury in the case of device-related pressure injury.

Data are presented and analyzed according to the study period (2015–2019 vs. 2020).

Statistical analysis

Demographic features of the population were presented using descriptive statistics. The mean (standard deviation) and median (interquartile range) were used for continuous variables with normal and *nonnormal distributions, respectively, and the number (percentage)* was used for categorical variables. The Shapiro–Wilk test was used to assess normality. The primary outcome was the incidence of pressure injuries and skin lesions calculated as the total number of babies with lesions divided by the number of hospitalized infants. Lesion incidence and distribution by the different types and severity of lesions were presented between the implementation and postimplementation phases.

Results

Infant characteristics

A total of 127 infants developed skin lesions that were recorded in the dedicated electronic dataset: 91 infants in the implementation period (out of 4298 infants admitted into the NICU) and 36 in the postimplementation period (out of 874 infants). Overall, 146 skin lesions were recorded (with the exclusion of diaper dermatitis that was analyzed separately): 19 infants developed 2 skin lesions (15 in the implementation period and 4 in the postimplementation period).

The infants' demographic characteristics are shown in Table 1.

Skin lesions

Fig. 1 shows a year-by-year description of the number and type of observed skin lesions; the dashed line indicates the separation of the two study periods.

An increase in the number of pressure injuries reported by the nursing staff was observed during the study time.

The incidence of pressure injuries slightly increased throughout the implementation period (2015–2019), from 1% (8/783 in 2015) to 2.7% (24/904 in 2019), reaching 3.9% (34/874) in the postimplementation period (2020).

Instead, the incidence of other skin lesions varied from 0.3% (implementation period) to 0.7% (postimplementation period).

The distribution of the three different types of lesions in the two study periods (implementation and postimplementation) was as follows: a) device-related pressure injuries 56.6% ($n = 60$) and 62.5% ($n = 25$), respectively; b) conventional pressure injuries 29.2% ($n = 31$) and 22.5% ($n = 9$), respectively; and c) other skin lesions 14.2% ($n = 15$) and 15.0% (n = 6), respectively.

In the context of device-related pressure injuries, NCPAP-related pressure injuries were the most common lesions in both periods (71.7% and 56.0%). Among the conventional pressure injuries, the occipital area was the most involved site (93.5% and 100.0%): only two lesions were located in a different anatomical site (one was a congenital lesion to the malleolus due to postural anomaly in utero; the other was located on the side of the abdomen in a baby with extreme edema). The other skin lesions (not pressure injuries) reported were tear injuries, extravasations, chemical or probe burns, and lesions of unknown origin; details are reported in Table 2.

When pressure injuries were categorized according to the NPIAP staging system, we observed an overall reduction in the severity of lesions: severe injuries (stage 3 and 4 and unstageable, US, lesions) decreased from 46.2% ($n = 42$) to 29.4% ($n = 10$), while milder forms (stage 1 and 2) increased from 56.0% ($n = 51$) to 70.6% ($n = 24$) from the implementation to postimplementation period.

Table 1
Infants' characteristics according to the study period: implementation (2015–2019) and postimplementation period (2020).

	IMPLEMENTATION	POSTIMPLEMENTATION
	2015–2019	2020
	(n = 91)	(n = 36)
Birth weight, *g*		
mean	*1597.1*	*1645.8*
SD	926.7	998.3
Gestational age, wks		
mean	30.8	31.0
SD	4.9	5.5
Gender		
Female, n (%)	41 (45.1)	19 (52.8)
Male, n (%)	50 (54.9)	17 (47.2)

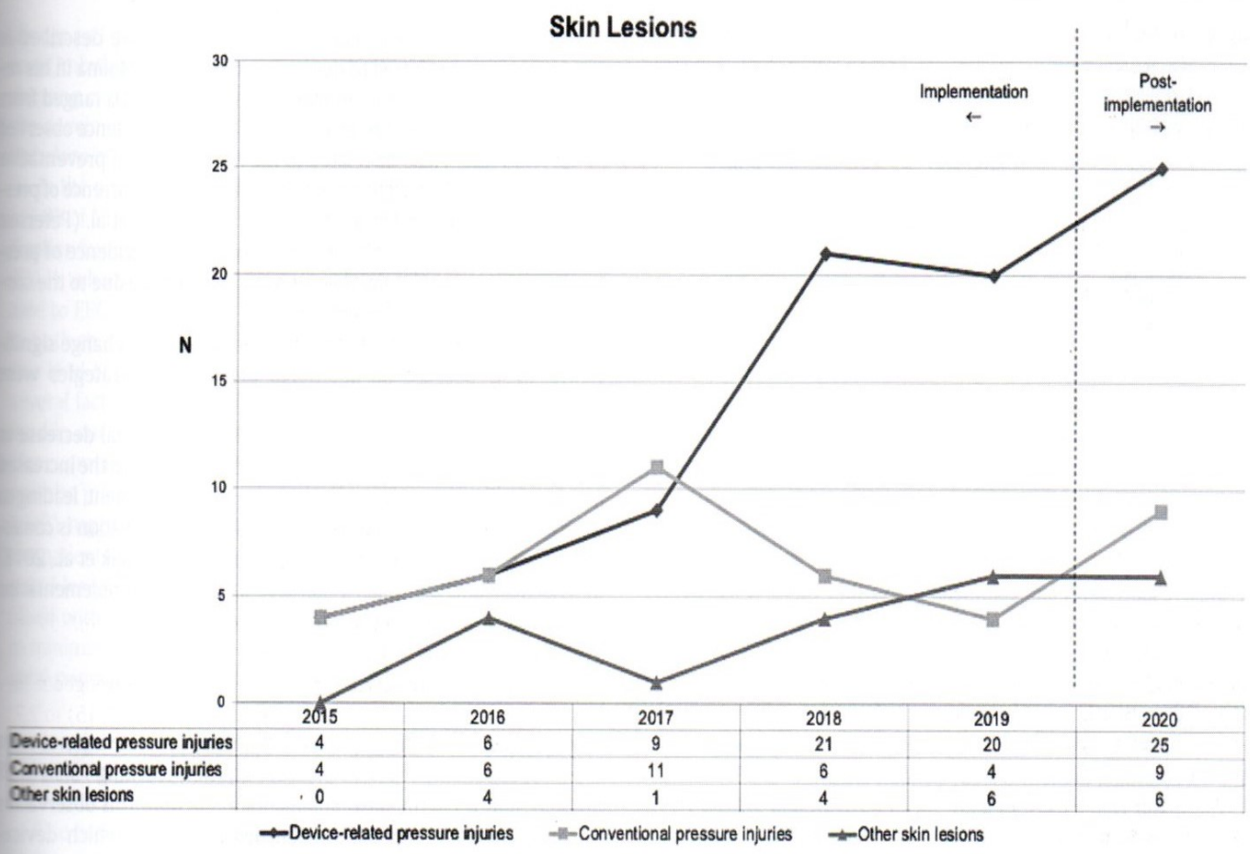

Fig. 1. Number of skin lesions per year according to the three categories (device-related pressure injuries, conventional pressure injuries and other skin lesions).

NCPAP-related pressure injuries

The characteristics (site and stage) of NCPAP-related pressure injuries according to the study period are shown in Table 3. Infants who developed NCPAP-related pressure injuries had a mean birth weight of 924.9 g (SD 384.8), a mean weight at pressure injury occurrence of 1027.6 g (SD 385.0), a gestational age at birth of 27.2 weeks (SD 2.7), and a female sex of 49.1%. Infants developing NCPAP-related pressure injuries during the two study periods had similar characteristics.

We observed a year-by-year increase in the absolute number of NCPAP-related pressure injuries that ranged from 2 (2015) to 14 (2020); nonetheless, milder forms were more represented throughout the study periods: severe forms decreased from 34.9% ($n = 15$) to 28.5% ($n = 4$) in the two periods, while milder lesions increased from 65.1% ($n = 28$) to 71.5% ($n = 10$).

NCPAP-related pressure injuries usually occurred precociously, presenting on average within a week from the beginning of noninvasive ventilation: 8.6 days (SD 12.3) after the start of NCPAP assistance. No association with the total number of noninvasive ventilations was observed (data not shown). Nose root (62.8% and 85.7% in the two

Table 2
Distribution of skin lesions (Device-related pressure injuries, Conventional pressure injuries, Other skin lesions).

	IMPLEMENTATION	POSTIMPLEMENTATION
	2015–2019	2020
	N (%)	N (%)
Device-related pressure injuries	**60 (56.6)**	**25 (62.5)**
Endotracheal Tube	2 (3.3)	3 (12.0)
NCPAP	43 (71.7)	14 (56.0)
Humidified High Flow Nasal Cannula (HHFNC)	1 (1.7)	0 (0.0)
Catheter	8 (13.3)	3[A] (12.0)
Electrodes/probes	4[B] (6.7)	5[C] (20.0)
Other	2[D] (3.3)	0 (0.0)
Conventional pressure injuries	**31 (29.2)**	**9 (22.5)**
Occipital area	29 (93.5)	9 (100.0)
Other	2[E] (6.5)	0 (0.0)
Other skin lesions	**15 (14.2)**	**6 (15)**
Tear injury	3 (20.0)	1 (16.7)
Extravasation	6 (40.0)	2 (33.3)
Burn	2 (13.3)	2 (33.3)
Other	4[F] (26.7)	1[G] (16.7)

[A] nasogastric tube, 1 infusion set.
[B] temperature probe, 3 aEEG/EEG electrodes.
[C] aEEG/EEG electrodes, 1 blood pressure cuff.
[D] tracheostomy baseplate, 1 tracheostomy.
[E] malleolus, 1 side of the abdomen.
[F] wound lesion, 2 unknown origin, 1 rubbing.
[G] forceps for vacuum extraction.

Table 3
NCPAP-related pressure injuries: site and stage of the lesions in the two periods (implementation and postimplementation).

	IMPLEMENTATION	POSTIMPLEMENTATION
	2015–2019	2020
	N (%)	N (%)
Site		
Columella	9 (20.9)	2 (14.3)
Root	27 (62.8)	12 (85.7)
Nose tip	1 (2.3)	0 (0.0)
Ear	3 (7.0)	0 (0.0)
Forehead	1 (2.3)	0 (0.0)
Nostril	2 (4.7)	0 (0.0)
Stage		
1	10 (23.2)	2 (14.3)
2	18 (41.9)	8 (57.2)
3	2 (4.7)	1 (7.1)
4	4 (9.3)	0 (0.0)
Unstageable	9 (20.9)	3 (21.4)

Table 4
Conventional pressure injuries: site and stage of the lesions in the two periods (implementation and postimplementation).

	IMPLEMENTATION	POSTIMPLEMENTATION
	2015–2019	2020
	N (%)	N (%)
Site		
Occipital area	29 (93.4)	9 (100.0)
Malleolus	1* (3.3)	0 (0.0)
Side of the abdomen	1 (3.3)	0 (0.0)
Stage		
1	2 (6.4)	0 (0.0)
2	6 (19.4)	6 (66.7)
3	3 (9.7)	0 (0.0)
4	0 (0.0)	0 (0.0)
Unstageable	20 (64.5)	3 (33.3)

* Congenital injury (due to postural anomaly in utero).

periods, respectively) and columella (20.9% and 14.3%, respectively) were the most commonly involved sites.

Conventional pressure injuries

The characteristics (site and stage) of infants' conventional pressure injuries, according to the two study periods, are presented in Table 4.

The infant characteristics were mean birth weight 2424.4 g (SD 705.2), mean weight at pressure injury 2890.3 g (SD 674.7), mean gestational age at birth 35.2 weeks (SD 3.7), and female sex 52.5%. Infants developing conventional pressure injuries in the implementation and postimplementation periods showed similar characteristics.

Conventional pressure injuries usually developed slowly: infants had a mean postnatal age of 26.0 days (SD 19.6).

When comparing implementation and postimplementation periods, the severity of the injuries was distributed differently: severe forms decreased from 74.2% ($n = 23$) to 33.3% ($n = 3$), while milder lesions increased from 25.8% ($n = 8$) to 66.7% ($n = 6$).

Diaper dermatitis

In 2020, diaper dermatitis was reported in 76 infants (8.5%). The infant characteristics were as follows: mean birth weight 2187.4 g (SD 1027.3), mean gestational age at birth 34.2 weeks (SD 3.8), mean weight at the occurrence of diaper dermatitis 2570.8 g (SD 933.1), and mean postnatal age at the date of diaper dermatitis report 25 days (SD 24.3). The distribution between males and females was similar: 52.6% and 47.4%, respectively.

Discussion

Our results confirm that skin lesions represent an emerging problem in the neonatal population deserving attention from health care professionals and that quality improvement and educational programs, together with the adoption of appropriate preventative as well as treatment interventions, could be effective in reducing the severity of pressure injuries.

In our NICU, a quality improvement and educational program was developed from 2015 until 2020. This initiative increased the awareness among caregivers about skin lesion assessment and management and allowed nurses to acquire knowledge and skills regarding preventative and treatment measures.

Our findings showed an apparent increase in the incidence of all skin lesions reported throughout the study period (2015–2020). However, this result might be biased by incomplete initial reporting from the nurse, as only after implementation skin lesions were systematically reported was a lower number of device-related pressure injuries in the first years reported. Nonetheless, the overall observed postimplementation incidence of pressure injuries we described is quite low (3.8%) compared to that reported by Garcia-Molina in his review, in which the incidence of pressure injuries in NICUs ranged from 3.7% to 21.6% (García-Molina et al., 2017). The lower incidence observed in our NICU might also be related to the introduction of preventative strategies that may have contributed to reducing the occurrence of pressure injuries. This trend is similar to that of Peterson et al. (Peterson et al., 2015), who reported an initial increase in the incidence of pressure injuries in the PICU and then a significant decrease due to the consolidation of their improvement process.

Instead, the incidence of other skin lesions did not change significantly, likely because no additional preventative strategies were included in our educational program.

Throughout the study period, we observed a gradual decrease in pressure injury severity. This finding is probably related to the increased awareness of the importance of skin care and its assessment, leading to the early detection and treatment of lesions. This observation is consistent with previous reports; for example, Kulik et al. (Kulik et al., 2018) described a reduction in skin lesion severity in the postimplementation phase of their preventative project.

Device-related pressure injuries

Our experience confirms that device-related pressure injuries were the most commonly reported pressure injuries, reaching 73.5% of all pressure injuries in the postimplementation period. This observation is consistent with previously published studies in which device-related pressure injuries accounted for 80% of all skin lesions investigated (García-Molina et al., 2018; Visscher & Taylor, 2014). NCPAP was responsible for most of the pressure injuries, and only one pressure injury occurred during HHFNC support, an alternative noninvasive ventilation strategy. These findings probably reflect the strategy for noninvasive respiratory ventilation used in our NICU, where NCPAP is the most commonly used support while HHFNC is usually dedicated to the weaning phase from respiratory support. However, we cannot rule out a specific detrimental effect of NCPAP, as demonstrated by Imbulana et al. (Imbulana et al., 2018), who found that HHFNC was associated with a significant reduction in nasal lesions compared to NCPAP (RR, 0,46; 95% CI 0,37 to 0,58).

In their systematic review, Imbulana et al. (Imbulana et al., 2018) suggested three main preventative strategies for NCPAP-related pressure injuries: 1) use of nasal barrier dressing; 2) NCPAP interface alternation; and 3) use of HHFNC as an alternative noninvasive ventilation strategy to NCPAP. The presence of a preventive dressing between the device support and the skin seems to be a useful strategy to reduce the risk of pressure injuries. Moreover, the interchange between nasal prongs and masks can help to relieve specific areas, such as the nasal septum and nostrils. These last two preventative measures have been introduced in our updated internal procedure (second half of 2019) and may have contributed to the lower incidence of pressure injuries and the decreased severity of NCPAP-related pressure injuries observed in the postimplementation period.

In our population, infants who developed NCPAP-related pressure injuries were more likely to be born preterm (83.0% of infants had gestational age < 30 weeks) and/or had a very low birth weight (90.6%), and the lesion developed at an average postnatal age of 1 week. These characteristics have already been described as predictive factors for the occurrence of NCPAP-related pressure injuries. In their prospective observational study Dai et al. (Dai et al., 2020) identified gestational age < 32 weeks as a risk factor associated with nasal trauma and reported an avarage interval between the application of NCPAP and the occurrence of NCPAP-related pressure injury of 4.72 days (SD, 4.78; range, 0–30). Imbulana et al. (Imbulana et al., 2018) reported that infants with gestational age < 30 weeks or very low birth weight were at higher risk of developing a NCPAP-related pressure injury. Furthermore, these authors also demonstrated that the incorrect use of nasal

prongs and masks (in terms of size or placement) are extrinsic risk factors (Imbulana et al., 2018) and suggested that the use of preventative dressing and the alternation of prongs with nasal masks might prevent the development of NCPAP-related pressure injuries (Dai et al., 2020; Imbulana et al., 2018).

In the postimplementation period, we observed 7 pressure injuries (16.0% of all device-related pressure injuries) caused by EEG electrodes. Similar findings were reported by Visscher et al. (Visscher & Taylor, 2014), who reported 14% of device-related pressure injuries attributable to EEG electrodes. In our study, these pressure injuries occurred in both the temporal, frontal and parietal areas. We speculated that this kind of pressure injury may be the result of the interplay among several factors: the type of electrode (silver-plated cup electrodes are used in our NICU), an inappropriate method of securing the electrodes (for example, using a NCPAP cap), prolonged neonatal EEG monitoring and the infants' skin characteristics. Mietzsch et al. (Mietzsch et al., 2019) suggested that the type of EEG electrodes should be tailored to the patients' needs based on gestational age, skin condition, and anticipated length of monitoring. The use of softgel-based electrodes, combined with thorough skin inspection, could be a reasonable alternative to minimize EEG electrode-related pressure injuries in the preterm neonatal population (El Ters et al., 2018).

Conventional pressure injuries

The occiput is reported to be (García-Molina et al., 2017; García-Molina et al., 2018; Kriesberg Lange et al., 2018; Meszes et al., 2017; Noonan et al., 2006; Peterson et al., 2015) the most commonly involved area in the neonatal population because of the large head volume, and our infants developed conventional pressure injuries almost exclusively at the occiput.

Gestational age and birth weight have been identified as nonmodifiable risk factors, thus establishing the importance of investigating modifiable risk factors before defining practice improvements and prevention strategies (August et al., 2018).

Our implementation protocol provided the introduction of a new polyurethane mattress. Our data cannot demonstrate the efficacy of this special mattress in reducing conventional pressure injuries, but they support a reduction in pressure injury severity.

Indeed, a high specificity foam mattress seems to reduce the risk of pressure injuries more than a common mattress or a cotton-made surface (García-Molina et al., 2017). A proactive use of therapeutic surfaces, which means placing the infant on special mattress before the patient eventually develops cardiopulmonary instability (in the postsurgery period or during extracorporeal assistance) (Peterson et al., 2015), is desirable. According to Peterson et al. (Peterson et al., 2015), altered skin perfusion, edema, multiple medical devices, poor hydration and nutrition and low tolerance of postural changes all contribute to the development of conventional pressure injuries that are usually located in the occipital area and in sites where tubes and infusion lines are in direct contact with thin skin. We observed conventional lesions in the occipital area in 33 infants (5 infants developed two conventional pressure injuries): invasive mechanical ventilation, reduced mobility due to continuous IV pharmacological sedation or intrinsic disease (neuromuscular disorders), one or multiple drains, postsurgical period, severe edema, systemic hypotension and ExtraCorporeal Membrane Oxygenation (ECMO) assistance were recurrent conditions in these patients.

The reduced severity of pressure injuries was supported by the fact that only two occipital lesions occurring in 2019 and 2020 were difficult to treat: in these infants, platelet gel was used to help their healing process. This treatment, the standard of care in adult patients, is still an innovative but efficient treatment in infants because platelet gel can stimulate and accelerate pressure injury healing and promote tissue regeneration. In addition, it might have an anti-inflammatory, analgesic, and antibacterial effect (Ferrario et al., 2021).

Infants with conventional pressure injuries were more mature and heavier than those experiencing device-related pressure injuries, and the lesion took a longer time to develop; these results are consistent with the prospective study by Visscher et al. (Visscher & Taylor, 2014).

Diaper dermatitis

In the first years of the implementation program, diaper dermatitis was rarely reported in the dataset, although diaper dermatitis is a common condition in infants: it can cause considerable pain and stress and can be troublesome for their caregivers (Merrill, 2015). During the postimplementation phase, reporting of diaper dermatitis significantly increased, and the incidence reached 8.5% (80% of all our diaper dermatitis cases were reported in the postimplementation period). The institution of a new diaper dermatitis preventive and treatment internal protocol may have contributed by increasing awareness about diaper dermatitis and the need for treatment to reduce infant discomfort.

Limitations

This study had several limitations. In the first years of the implementation period, we may have underestimated the occurrence of pressure injuries, as skin lesions were not systematically reported. Different preventative and treatment strategies were simultaneously introduced, thereby limiting the possibility of carrying out association analyses between interventions and the occurrence of pressure injuries and assessing the effectiveness of each single intervention. Due to the study design, our results cannot be generalized. Moreover, the lack of a person dedicated to data collection may have produced nonuniform data collection.

Implications for research

In the future, we aim to lower the incidence of skin lesions by consolidating our preventive and treatment strategies by providing a tailored treatment based on the early identification of individual risk factors, especially for NCPAP-related pressure injuries.

The development of new special materials and the use of new and innovative surfaces might be evaluated to reduce conventional pressure injuries.

Conclusion

Infants admitted to NICUs are at high risk of developing skin lesions, which can lead to an increased risk of infections, avoidable pain and discomfort and prolonged hospitalization. Among skin lesions, pressure injuries are the most common and depend on the interplay among intrinsic and extrinsic factors.

The institution of an educational program, the elaboration of an internal procedure and its continuous update have been effective strategies to standardize the skin assessment and care of infants and may have contributed to increased awareness in health care professionals, thus leading to prevention or early detection of skin lesions with low severity.

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CRediT authorship contribution statement

Barbara Fassino: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Silvia Ferrario:** Conceptualization, Writing – original draft. **Gabriele Sorrentino:** Writing – original draft, Visualization. **Ileana Adamini:** Conceptualization, Supervision, Writing – review & editing. **Nicola Pesenti:** Methodology, Formal

analysis. **Monica Fumagalli:** Methodology, Formal analysis, Writing – original draft, Visualization, Supervision, Writing – review & editing. **Fabio Mosca:** Supervision, Writing – review & editing. **Laura Plevani:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pedn.2023.01.009.

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