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Reducing Device-Related Pressure Injuries Associated With Noninvasive Ventilation in the Neonatal Intensive Care Unit

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BACKGROUND: Noninvasive ventilation (NIV) has become the preferable modality of respiratory support for spontaneously breathing premature infants in the neonatal ICU (NICU). Whereas NIV support contributes to the prevention of long-term respiratory sequelae from mechanical ventilation, the nasal interfaces used are well known for placing patients at risk for development of NIV device-related pressure injuries (PIs). After implementing clinical practice guidelines promoting the use of sealing NIV interfaces for respiratory support in a level IV NICU, an increase in the frequency of stage 2 or worse and deep tissue injury (DTI) PI was observed. We hypothesized that the implementation of a multifaceted skin care bundle (SCB) would reduce the incidence of NIV device-related PI. METHODS: Quality improvement methodology was used to evaluate the impact of implementing an SCB for patients supported with NIV via a nasal interface. Incidence rate of stage 2 or worse and DTI PI was reported per 100 NIV days over 4 distinct time periods: (1) pre-NIV guideline, (2) post-NIV guideline, (3) post SCB, and (4) sustainability phase. Incidence comparisons were made using one-sided *P* values from the Farrington-Manning test of equal risks with a significance level of 0.05. RESULTS: The NICU experienced a notable rise in NIV device-related PI after implementation of NIV guidelines (0.01 vs 0.34 per 100 NIV days; *P* = .01). After application of an SCB, a decrease in NIV device-related skin PI was achieved (0.34 vs 0.07 per 100 NIV days; *P* = .04), representing a 79% reduction. CONCLUSIONS: A collaborative and multidisciplinary team approach was used to promote engagement with clinical staff to address a preventable harm. The implementation of a multifaceted PI prevention bundle contributed to reducing harm while permitting the continued use of appropriate respiratory support to a highly vulnerable patient population in the NICU. *Key words: pressure injury; pressure ulcer; neonatal; skin; device-related pressure injury; noninvasive ventilation.* [Respir Care 0;0(0):1–●. © 0 Daedalus Enterprises]

Introduction

Noninvasive ventilation (NIV) has become the preferred modality of respiratory support for spontaneously breathing premature infants. In 2014, the American Academy of Pediatrics (AAP) recommended that CPAP be started at or soon after birth.[1] Randomized clinical trials have consistently demonstrated that the use of NIV leads to decreased need for invasive mechanical ventilation, reduction in lung injury associated with mechanical ventilation, as well as reduction in long-term negative respiratory outcomes.[2-7]

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This quality improvement project was performed at Johns Hopkins All Children's Hospital, Saint Petersburg, Florida.

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Despite its benefits on respiratory outcomes, NIV devices are commonly associated with traumatic skin injury. In a systematic review, nasal injury associated with the use of CPAP and short binasal prongs was frequently seen in preterm infants born younger than 30 weeks gestational age (GA) with pressure injury (PI) rates ranging from 20–100% in premature infants.[8] Although devices such as short binasal prongs or mask are more effective in delivering the prescribed pressures to the lower respiratory system when compared to nonsealing nasal interfaces, they are associated with increased risk of nasal trauma and skin PI.[9,10]

In 2016, following AAP recommendations and strategies to prevent bronchopulmonary dysplasia in premature infants, evidence-based clinical practice guidelines were released with recommendations for NIV support in preterm infants born with GA younger than 32 weeks at a level IV neonatal ICU (NICU) regional referral center. These guidelines recommended the delivery of NIV to preterm infants < 32 weeks gestation using short binasal prongs or mask rather than through a nonsealing nasal cannula. PI detection and reporting system already existed in the NICU, and as the use of these devices increased, a notable rise in the incidence of stage 2 or worse and DTI PI related to NIV was observed. Although the use of skin barrier products and the performance of skin assessments were common practice, there was not consistent methodology in the execution of these prevention measures. Therefore, a multidisciplinary team was assembled to address the problem of a preventable harm while maintaining best respiratory support practices for NICU patients. The team hypothesized that the implementation of a multifaceted skin care bundle (SCB) would reduce the incidence of NIV device-related skin PI. The team aimed to achieve the goal of a 50% reduction of stage 2 or worse and DTI PI NIV device-related PI over a period of 6 months when compared to the 12-month period following the implementation of respiratory support guidelines for premature infants.

QUICK LOOK

Current knowledge

Noninvasive ventilation (NIV) is commonly used to provide respiratory support for infants in the neonatal ICU (NICU). The nasal interfaces used for providing this support are well known to contribute to the development of device-related skin pressure injuries (PIs).

What this paper contributes to our knowledge

Consistent use of skin barrier products, frequent skin integrity assessments, proper device application and fit, and off-loading of pressure are important components of a neonatal NIV skin care bundle. A multidisciplinary team approach and the use of a multifaceted skin care bundle were shown to reduce the incidence of NIV device-related PIs in the NICU.

Methods

This quality improvement (QI) project was reviewed and acknowledged by the Johns Hopkins Medicine Institutional Review Board and was determined to not constitute human subjects research. QI methodology was used to evaluate the impact of an SCB to reduce the occurrence of NIV device-related PI. All infants admitted to a 97-bed level IV NICU being supported by NIV were monitored for the outcome of NIV device-related PI. PI detection and reporting systems in place since 2013 continued in a consistent manner throughout all phases of the project. This included notification of the medical team, consultation with a wound-ostomy nurse practitioner for assessment and staging, and entry of the injury into an internal PI database as well as entry into an electronic hospital safety reporting system when a PI was identified.

The ratio of respiratory therapists staffed in the NICU in relation to number of patients requiring respiratory support did not differ throughout the phases of the project, nor was there a change in the type or brand of nasal interface available in the unit during the course of this evaluation.

Stage 2, 3, 4, DTI, and unstageable injuries were reported in this evaluation. Stage 1 PIs were excluded. PIs were staged in accordance with the National Pressure Injury Advisory Panel.[11] Patients in the NICU received ventilator-driven NIV support using sealing short binasal prongs, nasal mask, or nasal cannula interfaces. The sealing NIV interface system consisted of a bonnet, short binasal prongs or mask (Fig. 1), and generator tubing that attached to the inspiratory and expiratory limbs of the ventilator circuit. Proper fit for the device was determined by a sizing guide that accompanied each device that indicated the correct bonnet and mask or prong size to be used to achieve optimal fit. Sealing interfaces were used for infants who met criteria per NIV guidelines (postextubation support for infants with birthweight < 1,000 g and primary support for infants with GA at birth under 32 weeks) or per medical provider prescription as clinically indicated. A nonsealing nasal cannula interface attached to the ventilator circuit was permitted for infants outside of these categories. All NIV support was ventilator driven via a Servo-i (Maquet, Solna, Sweden) or a Babylog VN500 (Dräger Medical, Lübeck, Germany).

After the first 3 months of NIV guideline implementation, a notable rise in reports of stage 2 or worse and DTI PI associated with NIV support was identified. As a result of this observed adverse outcome, a multidisciplinary team of professionals was assembled to discuss individual cases

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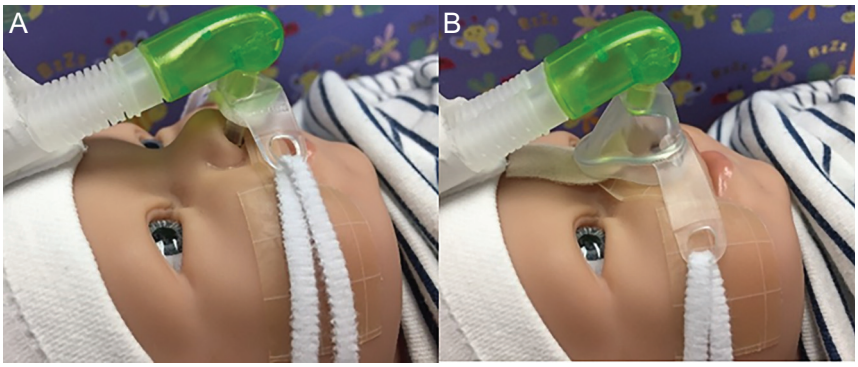

Fig. 1. Short binasal prongs (A) and nasal mask (B) with thin transparent hydrocolloid. Foam barrier to nasal prong base and foam barrier on nasal bridge with nasal mask.

of NIV device-related PI, review literature on prevention, and propose alternatives for respiratory support and/or skin care. The team consisted of respiratory therapists, nurses, a physician, and a certified wound/ostomy advanced-practice registered nurse.

Results from individual PI case reviews post-NIV guideline implementation demonstrated that most cases of NIV device-related PI were in patients supported with sealing nasal interfaces, with only one case attributed to a nasal cannula. Thus, the focus of the project concentrated on measures to preserve skin integrity when using sealing binasal prongs or mask. The team proposed an SCB with specific practice recommendations.

The primary outcome measure of the project was incidence of NIV device-related PI, which was reported per 100 NIV days, monthly for each phase of the project. Each occurrence of NIV device-related PI was reported to the wound/ostomy nurse practitioner who was responsible for PI staging and capturing the data in a customized spreadsheet. Data for NIV days were obtained from a preexisting report that contained information collected twice a day on the total number of ventilation devices in the noninvasive mode in use on a given day in the NICU (total number being an average for the day). The data for NIV days contained no information on type of ventilator device, nasal interface, or patient demographics. Data for total number of patients exposed to NIV across all phases of the project were extracted from an existing internal database and stratified for the following birthweight catagories: $< 1{,}000$ g, $\geq 1{,}000$ g and $\leq 1{,}500$ g, and $> 1{,}500$ g. The proportion of patients who experienced NIV device-related PI was also reported within each birthweight category.

Retrospective data for incidence of NIV device-related PI were collected for the 9-month period (July 2015–March 2016) preceding the introduction of NIV guidelines as well as for the 12-month period post-NIV guideline implementation (April 2016–March 2017). Data were prospectively collected for a 6-month period post-SCB implementation (April 2017–September 2017). Additional data were prospectively collected for 9 months to ensure sustainability of desired outcomes and compliance with the preventive measures (October 2017–June 2018). Patient demographic profile was collected for the population who developed stage 2 or worse and DTI NIV device-related PI.

Mean incidence of NIV device-related PI per 100 NIV days was calculated for each phase of the project. Comparisons were made using one-sided *P* values from the Farrington-Manning test of equal risks with a significance level of 0.05. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, North Carolina). Mean incidence of NIV device-related PI was also calculated per 1,000 NICU patient days to facilitate comparisons to nursing benchmarks for each phase of the project.

Interventions and plan-do-study-act cycles methodology were applied during the project. The project interventions consisted of (1) trial of various skin barrier products; (2) determining optimal placement of skin barriers on the face; (3) determining frequency and method of focused skin assessments; (4) education to NICU staff about NIV strategies, proper fit and application of NIV devices, and the recommended SCB; (5) developing processes for skin barrier placement in the delivery room for infants placed on NIV immediately after birth; (6) making bedside reference cards available to all patients on NIV; and (7) conducting process measure audits to assess compliance with recommendations.

The Use of Skin Barrier Products

The application of skin barrier products consisted of using a thin transparent hydrocolloid placed on the cheeks, upper lip, and bridge of nose. A transparent hydrocolloid was chosen as it allows for visualization of the skin underneath the barrier. A thin foam dressing was used as a pressure barrier and placed on the nasal bridge over the hydrocolloid barrier when using a nasal mask. The nasal septum was left uncovered as it is an area that is prone to staying moist when using nasal prongs or mask that may compromise the integrity of the hydrocolloid barrier and

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make skin integrity assessments of the area difficult to perform. A commercially available foam pressure barrier designed to fit over the nasal prongs was affixed to the base of the interface to provide additional protection when nasal prongs were used. Although the base of the short binasal prong interface used in the project is not intended to have direct contact with the nasal septum per the manufacturer's recommendations, in practice this can be difficult to achieve depending on the device fit or degree of patient movement. Care was taken to properly fit nasal prongs to the patient; however, the foam pressure barrier applied to the interface provided skin protection in the event the nasal prong base came in contact with the nasal septum.

Frequency of Skin Assessments

Focused skin assessments were recommended every 3 h and consisted of briefly removing the interface to assess cheeks, nasal bridge, nasal septum, and any skin in contact with the NIV interface. The thin foam pressure barrier used with nasal masks was lifted briefly to fully assess the nasal bridge area. Performing and ensuring the documentation of NIV skin integrity were the joint responsibility of the nurse and the respiratory therapist.

Education

To promote adherence to the proposed interventions, education was offered to all clinical care providers. Initial education began with a focus on overall respiratory management strategies for preterm infants to achieve the best long-term outcomes that included the importance of ensuring successful implementation of NIV and the rationale for prescription of sealing short binasal prongs or masks for optimal transmission of pressures to the lower airways. Further education was provided to nurses and respiratory therapists on the proper application and fit of the NIV system and recommended SCB. Education methods included electronic communication, live presentations, and a rolling cart with one-on-one bedside education material to clinicians. Physicians and advanced-practice providers were encouraged to include skin integrity as part of the daily rounds discussion and progress note documentation for patients on NIV support.

Information on the proportion of providers who received SCB training in relation to the total number of those who were eligible to receive education was monitored to ensure acceptable rates of communication of the new SCB and recommendations to prevent NIV device-related PI.

Skin Barrier Placement in Delivery Room

To promote compliance with SCB and to prevent delays in applying skin barriers after admission to the NICU, the delivery room team was equipped with skin protection packs containing all necessary skin barrier products. The team ensured that appropriate skin barriers were applied to patients receiving NIV support in the delivery room prior to transfer to the NICU.

Bedside Reference Materials

Bedside reference cards were placed in a plastic holder and attached to the ventilator for each patient being supported with NIV. The cards contained information on skin barrier placement, frequency of skin assessments, instructions on the proper application of the interface, and proper size and fit of the device. Handouts describing all elements of the SCB were also available to augment education to staff (Fig. 2).

Process Measure Audits

Fidelity and compliance to the intervention were verified by conducting random electronic medical records and bedside audits focusing on evaluation of (1) correct use of skin barriers, (2) proper sizing and fit of the NIV device, (3) adequate placement of ventilator circuit to prevent kinks and off-load pressure from the nasal interface, and (4) documentation of focused skin integrity assessment every 3 h. Audits were conducted monthly, and results were displayed in a dedicated area of the unit for staff viewing.

Results

Over the course of the project, 1,278 infants were exposed to NIV. There was a total of 9,741 NIV days over 36 months, which included all evaluated phases (pre-NIV guidelines, post-NIV guidelines, post SCB, and sustainability). Whereas infants with a birthweight at or below 1,500 g represented only 322/1,278 (25%) of the cohort, they accounted for 100% of those who experienced NIV device-related PI. The majority of infants who experienced NIV device-related PI had birthweight $<$ 1,000 g (10/16 [62.5%]), and the remainder (6/16 [37.5%]) had birthweight at or below 1,500 g. As indicated in Table 1, the highest proportion of infants exposed to NIV had a birthweight of $>$ 1,500 g (69–82%) followed by infants at or below 1,500 g (10–17%), with infants $<$ 1,000 g being the smallest proportion of subjects (7–13%) for each respective phase of the project. This distribution was consistent for each epoch. NIV device-related PI occurred in 10/138 (7%) of infants with birthweight of $<$ 1,000 g and in 6/184 (3%) of infants with birthweight at or below 1,500 g. No infants with birthweight of $>$ 1,500 g developed NIV-device related PI in any phase (Table 1).

Throughout all phases of the project, a total of 16 infants experienced stage 2 or worse and DTI NIV device-related

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ALL About My NIV

There should be a measuring tape at my bedside __ (check)

- My head circumference__ (Update with each new head circumference obtained)
- My hat size: White (19-21) Yellow (21-23) Red (23-25.5) Blue (25.5-28) Orange (28-30) Green (30-33) White (33-36)
- My prong size: (XS) {S) (M) (M-Wide) (L) (L-Wide) (XL)
- My mask size: (S) (M) (L) (XL)
- My skin barriers in use are: Foam Hydrocolloid Other:_____

Please be sure that:

- My skin integrity is assessed and documented Q 3 hours
- Make sure circuit and tubing are not pulling or twisted
- Velcro straps are not overtightened or pushed into eyes
- Extra skin barriers are kept at my bedside
- No skin barriers are placed on the septum

- My prong base is not pushed against my septum
- My mask and prongs are replaced as needed and as I grow
- My hat and ties get changed as I grow and with increased wear
- A HERO report is written for all skin issues
- Wipe/wash mask and prongs in between use with sterile water
- Use foam barrier with prongs (remove and replace when wet or soiled)

Fig. 2. Bedside reference card containing information about device application and skin care bundle kept in plastic sleeve on ventilator.

Table 1. Number of Infants Exposed to NIV, NIV Days, and Proportion of PI in NIV-Exposed Infants

	Pre-NIV Guideline	Post-NIV Guideline	Post SCB	Sustainability	Total
Number of months per phase, no.	9	12	6	9	36
Total exposed to NIV, *n*	290	424	243	321	1,278
Exposed to NIV by birthweight, *n* (%)					
< 1,000 g	38 (13)	56 (13)	20 (8)	24 (7)	138 (11)
≥ 1,000 ≤ 1,500 g	44 (15)	74 (17)	33 (14)	33 (10)	184 (14)
> 1,500 g	208 (72)	294 (69)	190 (78)	264 (82)	956 (75)
Total infants with PI, *n* (%)	1 (0.34)	11 (2.60)	1 (0.40)	3 (0.90)	16 (1.25)
< 1,000 g*	0	8 (14)	1 (5)	1 (4)	10 (7)
≥ 1,000 ≤ 1,500 g*	1 (2)	3 (4)	0	2 (6)	6 (3)
>1,500 g*	0	0	0	0	0
Total NIV days, no.	2,159	3,231	1,479	2,872	9,741

*Data presented as proportion of NIV-exposed infants who developed PI per birthweight category per phase of project.
NIV = noninvasive ventilation
PI = pressure injury

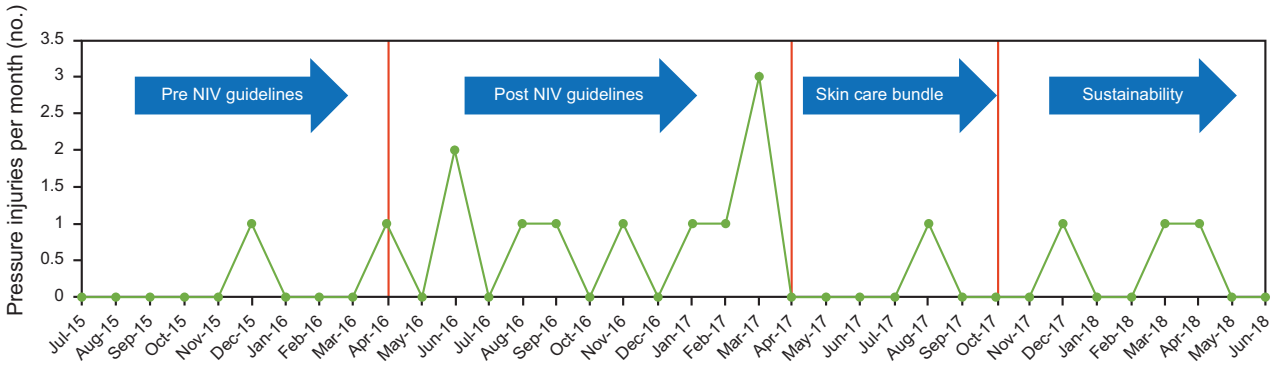

Fig. 3. Absolute number of stage 2 or worse and deep tissue pressure injuries reported per month for 36 months. Vertical red lines denote the different phases of the project.

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Table 2. General Characteristics of Infants With a PI

	Pre-NIV Guideline ($n = 1$)	Post-NIV Guideline ($n = 11$)	Post SCB ($n = 1$)	Sustainability ($n = 3$)
EGA, weeks	30	24 (24.0–31.5)	25	26 (25.5–31.5)
Birthweight, g	1,000	800 (695–955)	795	1,040 (977.5–1,125.0)
Weight at PI, g	1,000	980 (820–1,060)	790	1,070 (1,045–1,085)
Male/female, *n* (%)	1 (100)/0	7 (64)/4 (36)	0/1 (100)	2 (67)/1 (33)
Day of life at PI, d	3	11 (7.5–24.5)	13	11 (7–14)
Days on NIV at PI, d	3	6 (3.5–10.5)	12	9 (6–11)

Data are presented as median (interquartile range) or *n* (%).
NIV = noninvasive ventilation
SCB = skin care bundle
EGA = estimated gestational age
PI = pressure injury

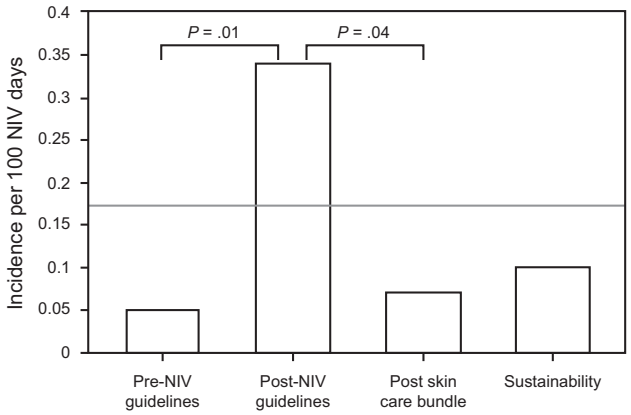

Fig. 4. Mean incidence per 100 NIV days of stage 2 or worse and deep tissue NIV device-related pressure injuries per phase of study. NIV = noninvasive ventilation.

PI (Fig. 3). Their characteristics are listed in Table 2. The majority of NIV device-related PI (11/16 [69%]) occurred shortly after the implementation of NIV guidelines, where injuries increased from 0.05 per 100 NIV days baseline, pre-guideline period to 0.34 per 100 NIV days, post NIV guideline; $P = .01$. After the SCB was implemented, the incidence of NIV device-related PI decreased from 0.34 to 0.07 per 100 NIV days; $P = .04$. The impact of the SCB represented a 79% reduction in stage 2 or worse and DTI NIV device-related PI, exceeding the set goal of a 50% reduction proposed by the multidisciplinary team. Unit performance was maintained within the set target threshhold for an additional 9 months, demonstrating sustainability (Fig. 4). Mean incidence rate of NIV device-related PI was also calculated per 1,000 NICU patient days for each phase of the study as follows: 0.05 (pre-NIV guideline), 0.42, (post-NIV guideline), 0.08 (post SCB), and 0.16 (sustainablity). The profile of NIV device-related PI is described in Table 3. During this 36-month evaluation, nasal PIs were most commonly located at the nasal bridge (9/16 [56%]) and nasal septum (6/16 [38%]), with 1/11 (6%) occurring to the side of the nose. All injuries to the nasal bridge were associated with the use of a nasal mask. Of the six injuries to the nasal septum, (4/6 [67%] were associated with sealing binasal prongs, and (2/6 [33%]) were associated with the use of a nasal cannula. One injury to the side of a nose was associated with the use of the nasal mask.

Measuring the reach of NIV and SCB education to eligible staff was a key component of project implementation. Formal dissemination of education regarding the rationale for NIV therapy was provided to the majority of nurses (138/170 [81%]) and respiratory therapists (34/39 [87%]) who provided care in the NICU over a period of 4 months. Education specific to the skin care bundle was provided to nurses (128/170 [75%]) and respiratory therapists (38/39 [97%]) over this same time period.

A formal audit system to assess SCB reliability was implemented midway through the intervention period that consisted of chart review and patient assessment. Adherence to the SCB was 110/156 (71%) for the 12 months evaluated. Audit findings for bundle elements not in compliance were as follows: incomplete or missing documentation of skin assessment 24/52 (46%), improperly applied or missing skin barriers 14/ 52 (27%), incorrect size or fit of device 11/52 (21%), and inappropriate circuit or interface position 3/52 (6%).

Discussion

The adoption of clinical practices supported by evidence that aim for the best long-term outcomes for extremely vulnerable and fragile patients is challenging. Early initiation of CPAP to manage respiratory distress syndrome in preterm infants is supported by the AAP and European consensus based on innumerous clinical trials and systematic reviews; however, they alert for the fact that all CPAP interfaces carry a risk of facial distortion and nasal trauma.[1,12-18] Severe nasal deformities consisting of necrosis, widening of the nares,

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Table 3. Pressure Injury Characteristics

	Pre-NIV Guideline ($n = 1$)	Post-NIV Guideline ($n = 11$)	Post SCB ($n = 1$)	Sustainability ($n = 3$)	Total ($n = 16$)
PI stage, *n* (%)					
2	0	6 (55)	1 (100)	1 (33)	8 (50)
3	0	1 (9)	0	0	1 (6)
4	0	0	0	0	0
Unstageable	0	1 (9)	0	0	1 (6)
DTI	1 (100)	3 (27)	0	2 (67)	6 (38)
Location of injury, *n* (%)					
Nasal septum	1 (100)	3 (27)	0	2 (67)	6 (38)
Nasal bridge	0	7 (64)	1 (100)	1 (33)	9 (56)
Side of nose	0	1 (9)	0	0	1 (6)
Interface type, *n* (%)					
Nasal mask	0	8 (73)	1 (100)	1 (33)	10 (62.5)
Binasal prongs (sealing)	0	2 (18)	0	2 (67)	4 (25.0)
Nasal cannula	1 (100)	1 (9)	0	0	2 (12.5)

NIV = noninvasive ventilation
SCB = skin care bundle
PI = pressure injury
DTI = deep tissue injury

and snubbing of the nose have been reported with prolonged use of NIV as well as long-term sequela beyond 2 y of age. These complications have long been thought to be preventable by modifications to the mechanism and methods of NIV support administration.[19,20]

Recent trials comparing high-flow nasal cannula (HFNC) with CPAP demonstrated that when used for preterm infants with respiratory distress HFNC resulted in a significantly higher rate of treatment failure than did CPAP. However, for all studies, CPAP with sealing interfaces had higher incidence of nasal trauma and NIV device-related PI as compared to HFNC.[21-23] Although sealing short binasal prongs and mask were available at our institution prior to NIV guideline implementation, there was heterogeneous methodology for the application of nasal interfaces, and nonsealing nasal cannula interfaces were commonly used at the discretion of the provider.

Education and Navigating Adaptive Change

The rise in incidence of NIV device-related PI subsequent to the implementation of NIV guidelines, which recommended the use of sealing nasal interfaces for optimal lower-airway pressure delivery, presented both technical and adaptive challenges in addressing the changes required for successful and safe NIV guideline implementation. Whereas technical challenges may be more straightforward to address, "Adaptive challenges can only be addressed through changes in people's priorities, beliefs, habits, and loyalties." [24] Although the evidence for the application of NIV support using sealing nasal interfaces is clear, the rise in NIV device-related PI was of great concern for providers caring for these infants in the NICU. This presented a challenge over the course of the project as the beliefs, attitudes, and habits of the clinicians did not ubiquitously support the practices being proposed. Indeed, not all care providers in the NICU shared the belief that providing NIV support to infants with sealing short binasal prongs or masks was in the best interest of the patient. Reports of concern for the development of skin injury, failure of the therapy, and patient discomfort were common. Failing to acknowledge the priorities, convictions, and culture that exist in a practice environment can lead to unsuccessful project implementation.[25] The team attempted to address this challenge through education to staff not only about the proposed SCB elements but also by providing education about the rationale for preference of a sealing nasal interface to provide NIV support for preterm infants.

To further promote engagement with staff, ongoing feedback was sought to facilitate plan-do-study-act cycles throughout the project. This dialogue with care providers was critical as it informed important aspects of the project, such as ensuring convenient availability of the necessary supplies, feedback on various skin barrier products, and determining feasibility of the SCB recommendations.

Application of Skin Barrier Products, Skin Integrity Assessments, Device Type, and Rotation

The core components of the NIV device-related PI prevention SCB were frequent and focused skin assessments

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and the consistent use and placement of specific skin barrier products. Two single-center randomized trials demonstrated a reduced risk of NIV device-related PI when a hydrocolloid barrier product was applied to the skin.[26,27] A single-center retrospective review demonstrated lower odds of developing NIV device-related PI when a foam barrier specifically designed for nasal prongs was used.[28] After trialing several different types of skin barrier products, the multidisciplinary team recommended the use of a thin transparent hydrocolloid and foam pressure barriers to areas of the skin that were in contact with the NIV interface.

One of the findings during SCB implementation was that placement of the skin barrier products and NIV support to newborns were perceived to cause a delay in initiating other interventions that were necessary shortly after admission to the NICU. To address this concern, the team recommended skin protection packs be available to the delivery room team. Skin barriers were placed on patients who required NIV prior to leaving the delivery room, which improved the efficiency in initiating NIV support upon admission to the NICU.

There is no consistent recommendation available for timing of skin integrity assessments during NIV support, and practices vary among institutions. Frequency of skin assessments reported in the literature range from every 1–6 h.[29,30] Given that care of infants in our NICU is clustered at 6-h intervals, a brief focused skin assessment under the NIV device was performed every 3 h so that half of the assessments would coordinate with already planned care interventions. Assessments were performed with the aim to minimize potential loss of positive airway pressure by quickly removing the interface to assess skin integrity under the device and placing it back. To facilitate proper documentation of skin integrity assessments, a dedicated field was added to the NIV section of the electronic medical records. Nurses and respiratory therapists were equally responsible to ensure that the focused skin integrity assessments were performed and documented, and collaboration was encouraged to minimize disruption in NIV support to the patient.

The idea of alternating mask and short binasal prongs routinely was also explored by the team. Although device rotation between nasal prongs and mask has been shown to confer some benefit in the reduction of NIV-related PIs,[31] the strategy was challenged by the potential loss in lung recruitment that could result from the process of frequent changes in interface and reports of better tolerance to one interface versus the other in certain patients. The team opted rather for frequent skin integrity assessments and interface rotation as needed based on the identification of poor fit or erythema related to high-pressure skin contact. Therefore, device rotation was performed as needed per clinician discretion based on findings during the focused skin assessment and not at a routine prescribed time interval. The impact of the rotation of interfaces was not documented and, therefore, not assessed during this project.

Interestingly, the majority of NIV-device related PIs in our center was associated with the use of a nasal mask. Although this finding was of concern, the team opted to continue using nasal masks in addition to nasal prongs as there is some evidence to suggest that the use of a nasal mask may reduce nasal CPAP failure and the occurrence of nasal injury.[32] The team opted to focus on PI prevention measures rather than discontinue the use of the nasal mask.

Process Measure Audits and Bedside Reference Materials

Process measure audits were performed to ensure adherence to the proposed SCB. Conducting these audits also allowed for real-time education and correction when opportunities for improvement were identified. Evaluating the elements not in compliance with SCB recommendations also provided important feedback to the project team so that common themes could be identified and addressed. For example, the most common bundle element not met was the documentation of the every 3-h skin assessment. Clinicians often verbalized that the assessment had been done but was not documented in the electronic medical records. This was addressed not only by providing just-in-time education but by adding a field for NIV skin integrity documentation within the NIV section for ease of documentation.

The convenient availability and use of education materials such as the reference card and handout were reported to reduce confusion among providers regarding the items needed to safely implement and maintain NIV support.

Incidence Reporting

According to the Agency for Healthcare Research and Quality (https://www.ahrq.gov. *Accessed December 6, 2020*), there is no national benchmark standard for reporting of PI. In this project, due to its relation to a respiratory support device, the team opted to report occurrences per 100 NIV days, which would target patients who are at risk for the outcome of interest (NIV device-related PI). Given that many units report PIs per 1,000 patient days, this was also reported to facilitate benchmarking across facilities. The NIV respiratory support guidelines targeted the small premature infant population; however, the number of NIV days included all patients exposed to NIV in the NICU, regardless of the interface in use, weight, or GA. Although information on the specific type of nasal interface used was available for all patients who developed NIV device-related PI, this information was not collected for patients exposed to NIV who did not develop PI. The specific association between type of nasal interface (sealing vs nonsealing) used by all patients exposed to NIV and occurrence of

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device-related PI cannot be made, making interpretation of incidence of device-specific PI and additional benchmark comparisons challenging.

This QI project demonstrated success in significantly decreasing the occurrence NIV device-related PI, a preventable adverse event, by nearly 80%. A limitation to be considered is the single-center nature of the QI project that may not make results generalizable to other NICUs. This endeavor used QI methodology to ensure that evidence-based best practices were applied to avoid a common and preventable adverse complication. Its aim was to evaluate overall unit performance for the outcome of NIV device-related PI; thus, it was beyond the scope the project to assess for risk factors associated with the development of this adverse event such as GA, birthweight, and number of d on NIV therapy, nor was an assessment made on the impact of NIV support on long-term pulmonary outcomes.

Conclusions

It is possible to provide adequate noninvasive respiratory support to very preterm neonates while avoiding its potential negative side effects. The increase in stage 2 or worse and DTI NIV device-related PI experienced in our center could be considered an unintended consequence of implementing guidelines that were meant to improve pulmonary outcomes. A multidisciplinary team approach and the implementation of a multifaceted PI prevention bundle contributed to reducing harm, while allowing for the continued use of the appropriate noninvasive respiratory support to a highly vulnerable patient population in the NICU.

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