Global Pediatric Health
Volume 8: 1–8

DOI: 10.1177/2333794X211010459
journals.sagepub.com/home/gph
SAGE

Incidence and Severity of Nasal Injuries in Preterm Infants Associated to Non-Invasive Ventilation Using Short Binasal Prong

Débora de Fátima Camillo Ribeiro, MD[1,2,3], Frieda Saicla Barros, PhD[2], Beatriz Luci Fernandes, PhD[3], Adriane Muller Nakato, PhD[3], and Percy Nohama, PhD[2,3]

Abstract

Short binasal prongs can cause skin and mucosal damage in the nostrils of preterm infants. The objective of this study was to investigate the incidence and severity of nasal injuries in preterm infants during the use of short binasal prongs as non-invasive ventilation (NIV) interfaces. A prospective observational study was carried out in the public hospital in a Southern Brazil. The incidence and severity of internal and external nasal injuries were evaluated in 28 preterm infants who required NIV using short binasal prongs for more than 24 hours. In order to identify possible causes of those nasal injuries, the expertise researcher physiotherapist has been carried empirical observations, analyzed the collected data, and correlated them to the literature data. A cause and effect diagram was prepared to present the main causes of the nasal injury occurred in the preterm infants assessed. The incidence of external nasal injuries was 67.86%, and internal ones 71.43%. The external nasal injuries were classified as Stage I (68.42%) and Stage II (31.58%). All the internal injuries had Stage II. The cause and effect diagram was organized into 5 categories containing 17 secondary causes of nasal injuries. There was a high incidence of Stage II-internal nasal injury and Stage I-external nasal injury in preterm infants submitted to NIV using prongs. The injuries genesis can be related to intrinsic characteristics of materials, health care, neonatal conditions, professional competence, and equipment issues.

Keywords

non-invasive ventilation, premature, Neonatal Intensive Care Unit, wound and injuries

Received February 17, 2021. Received revised April 03, 2021. Accepted for publication 24 March, 2021.

Introduction

Preterm infants have the risk of developing respiratory complications due to the immaturity of the respiratory system, and many times require ventilatory support.[1]

Non-invasive ventilation (NIV) provides ventilatory support without the need to establish an artificial airway.[2] NIV reduces the need for invasive mechanical ventilation, surfactant replacement, and oxygen supplementation in infants.[3] Furthermore, it promotes the stabilization of the chest wall and upper airway, reduces apneas, lung resistance, and work of breathing, improving tidal volume, oxygenation, and functional residual capacity.[4]

For NIV application, an interface device between equipment and patient is necessary.[5] There is a wide variety of interfaces of different sizes, types, shapes, and materials available in the market.[6] The masks and nasal prongs are the most common interfaces used.[5] However, in neonatology, the short binasal prongs are the most popular,[7] they may cause skin and mucosal damage in the nostrils and nasal septum.[8]

[1]Waldemar Monastier Hospital, Campo Largo, Paraná, Brazil
[2]Universidade Tecnológica Federal do Paraná, Curitiba, Paraná, Brazil
[3]Pontifícia Universidade Católica do Paraná, Curitiba, Paraná, Brazil

Corresponding Author:
Débora de Fátima Camillo Ribeiro, Graduate Program on Health Technology, Pontifícia Universidade Católica do Paraná, Rua Imaculada Conceição 1155, Curitiba, Paraná CEP 80215-901, Brazil.
Email: debora-camillo@hotmail.com

Injuries can arise as simple hyperemia, advance to necrosis, and culminate in the destruction of the columella and nasal septum.[9,10] Tissue damage compromises skin functions and becomes a gateway for infectious agents.[11] Nasal injuries may also limit the use of NIV in infants requiring this ventilatory support[12] and, it may be a source of discomfort.[9] Pain causes an increment in arterial and intracranial pressures, increasing the risk of interventricular hemorrhages and leading to changes in preterm infants' motor development.[13]

The knowledge of the variables associated with the development of injuries due to the use of NIV can help direct infant care and contribute to the elaboration of protocols and training of the multidisciplinary team who are responsible for infants.[14,15]

From the scenario described here, we investigated the incidence and severity of nasal injuries in preterm infants during the use of nasal prongs as non-invasive ventilation interfaces, in the Neonatal Intensive Care Unit (NICU) of a public hospital situated in the metropolitan region of Curitiba, Paraná, in the south region of Brazil.

Material and Methods

This prospective observational study was carried out in 14 months in order to investigate the incidence and severity of nasal injuries in infants who required NIV through prongs. The essay has consisted of the data collection and their correlation with probable causes of these occurrences diagnosed by an expert physiotherapist.

Participants

Twenty-eight infants of both sexes had participated in this study, without distinction of ethnicity, class, or social group, with gestational age inferior to 37 weeks, submitted to NIV as initial ventilatory support or during weaning, for a minimum of 24 hours. Infants with nasal deformities or who had remained in NIV for a period lesser than 24 hours were excluded.

Procedures

Preterm infants received NIV via the Inter® Neo mechanical ventilator. Nasal prongs of 3 different brands (A, B, and C), new or sterilized, were selected according to the availability of the material during the NIV use.

All infants were submitted to an evaluation protocol consisting of neonatal data collection and visual inspection, which was always carried out by a single researcher. This researcher is a physiotherapist specialized in intensive care, and he has previously worked in the assessment and reduction of nasal injury in newborns in other investigations.

Collected neonatal data had included sex, gestational age, birth weight, and NIV duration.

During the clinical inspection, the researcher has looked for skin changes internally and externally to the nostrils. Injuries were graded according to the classification proposed by Fischer et al[9]: (a) Stage I: intact skin with non-blanchable erythema; (b) Stage II: partial loss of dermis thickness, presenting as a superficial wound, red bed, no crust; and (c) Stage III: necrosis and total tissue loss.

The assessments were performed before NIV use and then every 24 hours, always by the same researcher, until the medical suspension of the apparatus. The stage of the injury was recorded daily.

The same physiotherapist researcher, before each infants' daily nasal evaluation, checked for possible causes that could be associated with nasal injury in the NICU studied. From the survey searching for detecting the possible causes of the nasal injuries, for better understanding, the research team decided to present the results through a Cause-and-Effect Diagram (Ishikawa diagram).[16]

This type of diagram is useful in helping to understand the causes of the appearance of nasal injury and organize their mutual relationship. From the understanding of these causes, the ICU hospital service will be to able develop specific preventive actions.

Modeling for Nasal Injuries Genesis

A specialized physiotherapist has carried empirical observations beyond the analysis of the collected data and the available literature to investigate possible causes of those nasal injuries.

Before the daily evaluation of the nose, the physiotherapist observed the infant using NIV and the whole environment in which he was inserted in search of the causes that could lead to nasal injuries. These possible causes have been noted by the physiotherapist and posteriorly searched in the literature to verify whether they could be linked to the development of a nasal injury.

In order to present the genesis of the injuries occurred in the infants assessed, a cause and effect diagram was modelled.

The nasal injury was defined as the problem to be examined and from the possible causes raised by the physiotherapist, we defined 5 main categories of causes. Therefore, each possible cause listed by the physiotherapist was classified as a subcategory of 1 of the 5 main categories. This is an innovative, abridged, and attractive illustration that offers all relevant information on the causes and effects of these nasal injuries.

Table 1. Characteristics of All Preterm Infants Who Participated of the Essay and Used Non-Invasive Ventilation.[a]

Variables	External nasal injury			Internal nasal injury		
	With injury (n = 19)	Without injury (n = 9)	*P*	With injury (n = 20)	Without injury (n = 8)	*P*
Sex (female %)	8 (42.1)	8 (88.9)	.039*	11 (55.0)	5 (62.5)	1.000
Gestational age (weeks)	30.7 ± 3.2	32.1 ± 4.4	.207	31.1 ± 3.5	31.3 ± 4.0	.919
Birth weight (g)	1375.3 ± 472.7	1901.0 ± 864.4	.116	1536.3 ± 586.4	1564.3 ± 857.8	.819
NIV time (h:min)	106:26 ± 81:35	75:08 ± 65:05	.184	118:49 ± 80:33	40:15 ± 12:37	<.001*

[a]Values of mean ± standard deviation or absolute frequency (percentage) of variables of interest in 28 preterm infants with and without nasal injury.
Abbreviation: NIV, non-invasive ventilation.
*$P < .05$.

Statistical Analysis

Statistical analysis were performed with the statistical package GraphPad PRISM. Variables were described according to type: for quantitative variables, means and their standard deviations; for ordinal qualitative variables, medians, and maximum and minimum values; for nominal (categorical) variables, absolute and relative (percentage) frequencies. For differences between infants with and without nasal injury, Fisher's exact test was applied to nominal variables, and the Mann-Whitney test was applied to quantitative variables, at a 5% significance level ($P = .05$). Correlations between the degree of external injury and birth weight, gestational age, and NIV duration were analyzed via Spearman's rank correlation coefficient.

Results

Two hundred ten infants were admitted to the NICU: 83 of them required NIV. Among the infants who had used NIV, 44 of them had less than 37 weeks of gestational age, and among these, 28 met the inclusion criteria. Sixteen (57.14%) were female, and 12 (42.86%) were male. Mean gestational age was 31.14 ± 3.59 weeks, and mean birth weight was 1544.25 ± 657.96 g. Also, the average NIV time application has reached 96 hours 22 minutes ± 76 hours 54 minutes.

The incidence of external nasal injury has reached 67.86% (19 infants), 13 of them were stage I and 6 stage II, and the incidence of internal nasal injury has hit 71.43% (20 infants), all stage II. Table 1 presents the demographic characteristics of all infants assessed during the clinical essay.

The frequency and severity of external and internal nasal injuries among the 28 infants, related to gestational age, birth weight, and NIV permanence, are described in Table 2.

From 28 infants, only 4 (14.29%) have not developed nasal injury. Fifteen volunteers (53.57%) presented internal and external injury concomitantly, all internal nasal injury being classified as Stage II, 10 external nasal injuries were classified as stage I, and 5 external injuries were classified as Stage II. Four volunteers (14.29%) developed only external nasal injury, 3 of them were stage I, and 1 was stage II, whereas 5 infants (17.86%) had only internal nasal injuries, all stage II.

When correlating the external injury stage with gestational age, birth weight, and NIV length, it was verified that weight and NIV length presented statistically significant differences ($P < .05$). The strength of the correlation between these variables, however, was weak ($.25 \leq r < .5$). When the stage of internal injury was correlated with the other variables, only NIV length presented statistical significance, with a moderate association ($.5 \leq r < .75$). These data are presented in Table 3.

Graphical Model for Representing Nasal Injuries' Genesis

Figure 1 illustrates the possible causes of injury organized in a cause and effect diagram.

As the cause and effect diagram may represent graphically the possible primary and secondary causes of injury organized, we optioned for this innovative abridged mode. It was based on empirical observations of infants who used NIV, carried out by the intensive care physiotherapist, in addition to the analysis of the data collected and the available literature.[8,9,11,14,17-25]

The diagram was divided into 5 primary cause categories: material, healthcare, neonatal conditions, professional competence, and equipment. Nasal injuries may be related to the prong model and its sterilization process, both associated with the hardness of the material. Besides, the injury may be associated with the prong

Table 2. Frequency and Severity of External and Internal Nasal Injuries in Preterm Infants Submitted to Non-Invasive Ventilation.[a]

	External nasal injury		Internal nasal injury	
Variable	Stage I (n = 13) %	Stage II (n = 6) %	Stage I (n = 0) %	Stage II (n = 20) %
Gestational age				
<28 weeks	1 (7.69)	3 (50.00)	0 (0.00)	4 (20.00)
28-31 weeks	5 (38.46)	1 (16.67)	0 (0.00)	6 (30.00)
≥32 weeks	7 (53.85)	2 (33.33)	0 (0.00)	10 (50.00)
Birth weight				
<1000 g	1 (7.69)	3 (50.00)	0 (0.00)	4 (20.00)
1000-1499 g	6 (46.15)	2 (33.33)	0 (0.00)	7 (35.00)
1500-2499 g	6 (46.15)	1 (16,67)	0 (0.00)	8 (40.00)
≥2500 g	0 (0.00)	0 (0.00)	0 (0.00)	1 (5.00)
NIV time				
24-48 hours	4 (30.77)	1 (16.67)	0 (0.00)	2 (10.00)
49-72 hours	3 (23.08)	0 (0.00)	0 (0.00)	5 (25.00)
73-96 hours	3 (23.08)	1 (16.67)	0 (0.00)	5 (25.00)
>96 hours	3 (23.08)	4 (66.67)	0 (0.00)	8 (40.00)

[a]Values of absolute frequency (percentage) of the injury stage in the preterm infants studied concerning gestational age, birth weight and NIV time.
Abbreviation: NIV, non-invasive ventilation.

Table 3. Correlation between External Injury Stage and Gestational Age, Birth Weight and Time of Non-Invasive Ventilation.[a]

	Grade of external nasal injury		Grade of internal nasal injury	
Variables	*r*	*P*	*r*	*P*
Gestational age	−0.27	.162	−0.02	.901
Birth weight	−0.42	.024*	0.05	.805
NIV time	0.40	.036*	0.68	<.001*

Note: The value of "*P*" corresponds to statistical significance. The value of "*r*" indicates the direction and intensity of the correlation. If the "*r*" signal is negative, the variables are inversely proportional. If the signal is positive, the variables are directly proportional. The intensity of the correlation is given by the modulus value of "*r*," in which: $r = 0$ absence of correlation; $0 < r < 0.25$ Negligible correlation; $0.25 \leq r < 0.5$ Weak correlation; $0.5 \leq r < 0.75$ Moderate correlation; $0.75 \leq r < 1$ Strong correlation; $r = 1$ perfect correlation.
Abbreviation: NIV, non-invasive ventilation.
[a]Spearman's correlation coefficient (*r*) and significance (*P*) value associated with the relationship between external and internal lesion stage and 3 variables studied in 28 preterm infants submitted to non-invasive ventilation (NIV).
*$P < .05$.

design. In the NICU studied, the prongs are sterilized and there are 3 different models of the prong for use. In the healthcare category, possible secondary factors of nasal injury are the prong dimensions, infant positioning, and nasal prong positioning, fixation and positioning of the NIV apparatus. In this NICU, the choice of the prong size is achieved by the physiotherapist according to infant weight. The apparatus is fixed in the infant through tubular knitted caps associated with adhesive tape or it is fixed with NIV specific caps. The infant care in NIV is realized by nurses, assistant nurses, doctors, and physiotherapists.

Involving neonatal conditions, a possible secondary that causes injury are prematurity, low birth weight, anatomical characteristics of the preterm infants' nose, behavioral status, and NIV duration, the latter directly dependent on the infants' clinical diagnosis. In the professional competence category, the secondary factors involve lack of training, lack of professional experience, and lack of commitment of the professional to provide adequate care to the infant. Finally, in the equipment category, injuries may be related to the malfunction of the humidifier.

Discussion

The incidence of external nasal injury reached 67.86%, similar to the results found by others studies[18,24] that

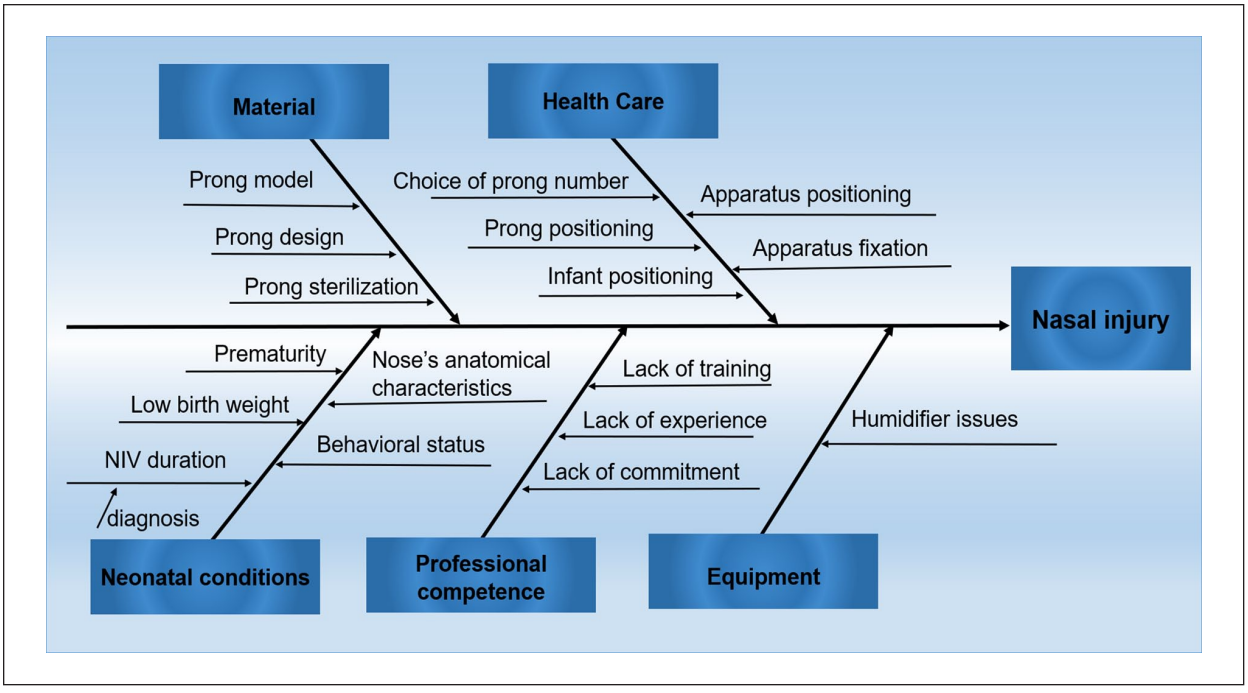

Figure 1. Cause and effect diagram.

evaluated the incidence and risk factors in preterm infants of low birth weight.

We found that 68.42% of the external nasal injuries presented Stage I, while 31.58% presented Stage II. An important aspect being emphasized is the non-occurrence of Stage III injuries. Aiming at the prevention of injuries, the studied NICU had a protocol that implemented nasal protections during NIV. It should be noted that the infants evaluated in this study had hydrocolloid or silicone nasal protections. This practice may have been the reason for the absence of Stage III injuries.

Sousa et al[24] had assessed 47 preterm infants who had required NIV using prongs. They observed 32 occurrences of nasal injury (68.1%) in infants being 43.7% classified as Stage I, 50% in Stage II, and 6.3% in Stage III. It should be emphasized that they had not used nasal protection in infants submitted to NIV, the reason for the more severe injury in this group.

When we associate external injury stage, birth weight, and NIV, length, we found that lower weight preterm infants and those who remained under NIV for longer periods developed more severe stages of external nasal injury. These findings are similar to other studies[9,18,26] in which were observed that preterm infants who stay for long periods under NIV are more susceptible to developing nasal injuries. Due to the immaturity of their integumentary system,[27] preterm infants are more susceptible to develop injuries. They have a poorly developed epidermal barrier, which leads to skin injury when some areas are compressed.[28] Besides, the immaturity of their respiratory system usually requires long periods in NIV, increasing the chances of injuries development.[18]

Until the moment, we have not found neonatology studies evaluating internal nasal injuries due to the use of the NIV. This study found an internal injury incidence superior to 70%; the severity of injuries was Stage II in 100% of the cases.

A statistically significant difference ($P < .001$) was observed in the NIV duration variable between infants with and without internal nasal injury. Also, Spearman's correlation showed that infants who remained under NIV for longer periods presented more advanced injuries, and the correlation between NIV duration and severity of the injury was moderate ($r = .68$). NIV duration is considered a risk factor for the development of nasal injuries: the longer the time under NIV, the greater the risk of developing injuries.[9,18,24]

A cause and effect diagram was created from causes diagnosed by the physiotherapist, based on data collection, daily observations of the infants submitted to NIV, environment conditions associated, and available literature.

According to the proposed diagram, 5 primary injury categories stood out: materials, health care, neonatal conditions, professional competence, and equipment.

In the "material" category, the possible secondary causes of injury were the prong model and design, as well as its sterilization procedure. The appearance of nasal injuries may be associated with the prong manufacturer, concerning the quality of materials and design.[22] Flexible prong and with curves insertion catheters are more effective than straight insertion catheters prongs[29] and can prevent injury.[25]

In the studied period, the NICU had 3 different models of prongs, new or reused. These models differed from each other by the format of insertion catheters, prong length, and by silicone softness, such parameters were seen as possible causes of nasal injury by the physiotherapist. However, the comparison of the effects of these distinct models is beyond the scope of this study.

Nasal prongs are supposed to be disposable. However, their reuse has been observed in many Brazilian NICUs.[18] The sterilization process causes the degradation of the polymeric material from which the device is manufactured, turning it more rigid and prone to injury the immature tissue of the newborn nostrils.[8] The NICU of the present study has been using both new and reused prongs.

The second category of possible primary causes of nasal injury was entitled "health care," and includes: prong number, prong and infant positioning, apparatus fixation and positioning.

The causes raised by the physiotherapist corroborate the literature because prongs with insertion catheters smaller than the diameter of the nostrils allow increased mobility of the prongs, can lead to nasal injury.[8] Besides, if the prong is too small, the insertion catheters do not fit properly in the nostrils and occurs positive pressure loss, thereby jeopardizing effectiveness of treatment. To compensate for leakage, the professionals can press erroneously the prong on the nasal structures, increasing the chances of injury.[25]

According to Nascimento et al,[8] the size and inadequate prong fixation are essential factors for the occurrence of injury. Regarding positioning, the prong should be adjusted in such a way that it does not touch the nasal septum,[8] and the NIV tube should not suffer traction.[25]

The NICU studied the physiotherapist is responsible for choose the prong's size and fixing in the infant. The choose prong's size depends on their body weight at the time of NIV implementation.[21] However, in clinical practice, the relationship between prong dimensions and the infant's body weight does not always guarantee that the infant will receive a prong of an appropriate size.[15] Therefore constant inspection of the prong and its positioning on the infant's skin can prevent the outset of injuries.[25]

The third primary cause category refers to "neonatal conditions." By collecting data on the incidence and severity of the injury and its correlation with gestational age, birth weight, and time under NIV, the physiotherapist concluded that these parameters were associated with injury nasal. According to the literature[9,11,20,26] prematurity and low birth weight are risk factors for the development of injuries, and the prolonged use of NIV may increase the probability of injury to nasal structures, pressed by the nasal prong. These factors are inherent to preterm infants, making them more susceptible to injury, implying redoubled health care.

The fourth category of injury causes involves "professional competence," which includes: lack of training, lack of experience, and lack of commitment of the health professional. Training and collective involvement in improving the use of the NIV are key components for the optimal performance of this ventilatory support.[22]

It is possible observe that the fourth category of injury causes is directly related to the "health care category," because the treatment given to the infants in NIV depends on the professional competence, in other words, it depends on how much this professional was previously trained and qualified to his jobs, how experienced he is and how committed and involved he is with the care of premature infants hospitalized in the NICU.

The fifth and last category addressed in the cause and effect diagram is "equipment." The secondary causes raised by the physiotherapist were: problems with the system's humidifier. During the installation and permanence of the infant in NIV, it is necessary to make sure that humidification and heating of the gases are adequate.[25] The temperature of gases must be set at 37°C.[19] Problems in the humidifier may cause drying of the nasal mucosa and make the infant more susceptible to nasal injury.

A limitation of the present study is related to the methodology used to survey the possible causes associated with the nasal injury, which consisted of unsystematic observations carried out by a single professional. To scientifically prove that these causes are significant to the occurrence of injuries in infants submitted to NIV, it is necessary to perform studies that evaluate the relationship of each of the possible causes with the development of the nasal injury.

Conclusion

Data indicate a high incidence of these injuries in preterm infants who received NIV using nasal prongs.

The severity of the external nasal injury was directly proportional to NIV duration and inversely proportional

to birth weight, just as the severity of the internal nasal injury was directly proportional to NIV duration.

The main causes of nasal injuries are related to the characteristics of prong material, equipment issues, health care, neonatal conditions, and professional competence.

We hope that these results contribute to sensitizing multi-professional healthcare teams about the incidence and causes of nasal injuries, and to the fact that preventive action must be done to minimize nasal injury in infants who undergo NIV using prongs.

Acknowledgments

We thank Fundação Araucária, Secretaria de Estado da Ciência, Tecnologia e Ensino Superior do Paraná (SETI), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for scholarships, and Waldemar Monastier Children's Hospital directy for allowing the study to be performed on the NICU's premises, and the NICU's physiotherapy team for helping to develop this study.

Author Contributions

All authors conceptualized and designed the study. DFCR contributed on the acquisition, analysis, and interpretation of data, and drafted the initial manuscript. FSB, BLF, AMN, and PN contributed on data analysis and interpretation, reviewed, and approved the final draft of the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethics Approval and Informed Consent

This study was performed in accordance with national and international requirements that conduct ethics in research involving human beings, following the Declaration of Helsinki, and approved by the Ethics Committee on Research Involving Human Beings of the Universidade Tecnológica Federal do Paraná—UTFPR under Approval Letter number 42718915.4.0000.5547. The newborns' parents were informed about the study and provided written informed consent.

ORCID iD

Débora de Fátima Camillo Ribeiro https://orcid.org/0000-0003-4482-8574

References

1. Garg S, Sinha S. Non-invasive ventilation in premature infants: based on evidence or habit. *J Clin Neonatol*. 2013;2:155-159.
2. Amaddeo A, Frapin A, Fauroux B. Long-term non-invasive ventilation in children. *Lancet Respir Med*. 2016;4:999-1008.
3. Abelenda VLB, Valente TCO, Marinho CL, Lopes AJ. Effects of underwater bubble CPAP on very-low-birth-weight preterm newborns in the delivery room and after transport to the neonatal intensive care unit. *J Child Health Care*. 2018;22:216-227.
4. Owen LS, Manley BJ, Davis PG, Doyle LW. The evolution of modern respiratory care for preterm infants. *Lancet*. 2017;389:1649-1659.
5. Boel L, Broad K, Chakraborty M. Non-invasive respiratory support in newborn infants. *Paediatr Child Health*. 2018;28:6-12.
6. Robert D, Argaud L. Clinical review: long-term noninvasive ventilation. *Crit Care*. 2007;11:210.
7. Gupta N, Saini SS, Murki S, Kumar P, Deorari A. Continuous positive airway pressure in preterm neonates: an update of current evidence and implications for developing countries. *Indian Pediatr*. 2015;52:319-328.
8. Nascimento RM, Ferreira ALC, Coutinho ACFP, Veríssimo RCSS. The frequency of nasal injury in newborns due to the use of continuous positive airway pressure with prongs. *Rev Latino Am Enfermagem*. 2009;17:489-494.
9. Fischer C, Bertelle V, Hohlfeld J, Forcada-Guex M, Stadelmann-Diaw C, Tolsa JF. Nasal trauma due to continuous positive airway pressure in neonates. *Arch Dis Child Fetal Neonatal Ed*. 2010;95:F447-F451.
10. Li Y, Sepulveda A, Buchanan EP. Late presenting nasal deformities after nasal continuous positive airway pressure injury: 33-year experience. *J Plast Reconstr Aesthet Surg*. 2015;68:339-343.
11. Imbulana DI, Manley BJ, Dawson JA, Davis PG, Owen LS. Nasal injury in preterm infants receiving non-invasive respiratory support: a systematic review. *Arch Dis Child Fetal Neonatal Ed*. 2018;103:F29-F35.
12. Carlisle HR, Kamlin CO, Owen LS, Davis PG, Morley CJ. Oral continuous positive airway pressure (CPAP) following nasal injury in a preterm infant. *Arch Dis Child Fetal Neonatal Ed*. 2010;95:F142-F143.
13. Bouza H. The impact of pain in the immature brain. *J Matern Fetal Neonatal Med*. 2009;22:722-732.
14. Milligan PS, Goldstein MR. Implementation of an evidence-based non-invasive respiratory support (NIRS) bundle in the NICU to decrease nasal injury complications. *J Neonatal Nurs*. 2017;23:89-98.
15. Ribeiro DFC, Barros FS, Fernandes BL, Nakato AM, Nohama P. Nasal prongs: risks, injuries incidence and preventive approaches associated with their use in newborns. *J Multidiscip Healthc*. 2020;13:527-537.
16. Ishikawa K. *Guide to Quality Control*. Asian Productivity Organization; 1976.

17. Alessi S. Evidence regarding the use of bubble continuous positive airway pressure in the extremely low birth-weight infant: benefits, challenges, and implications for nursing practice. *Adv Neonatal Care*. 2018;18: 199-207.
18. Bonfim Sde F, de Vasconcelos MG, de Sousa NF, da Silva DV, Leal LP. Nasal septum injury in preterm infants using nasal prongs. *Rev Latino Am Enfermagem*. 2014;22: 826-833.
19. Bonner KM, Mainous RO. The nursing care of the infant receiving bubble CPAP therapy. *Adv Neonatal Care*. 2008;8:78-95.
20. Casey JL, Newberry D, Jnah A. Early Bubble continuous positive airway pressure: investigating interprofessional best practices for the NICU team. *Neonatal Netw*. 2016;35:125-134.
21. Chen C-Y, Chou A-K, Chen Y-L, Chou H-C, Tsao P-N, Hsieh W-S. Quality improvement of nasal continuous positive airway pressure therapy in neonatal intensive care unit. *Pediatr Neonatol*. 2017;58:229-235.
22. Ota NT, Davidson J, Guinsburg R. Early nasal injury resulting from the use of nasal prongs in preterm infants with very low birth weight: a pilot study. *Rev Bras Ter Intensiva*. 2013;25:245-250.
23. Sahni R, Schiaratura M, Polin RA. Strategies for the prevention of continuous positive airway pressure failure. *Semin Fetal Neonatal Med*. 2016;21:196-203.
24. Sousa NFC, Bonfim SFSF, Vasconcelos MGL, Bezerra JLO, Silva DVC, Leal LP. Prevalence of nasal septum injury in premature infants using nasal prongs. *Rev Esc Enferm USP*. 2013;47:1285-1290.
25. Squires AJ, Hyndman M. Prevention of nasal injuries secondary to NCPAP application in the ELBW infant. *Neonatal Netw*. 2009;28:13-27.
26. Yong SC, Chen SJ, Boo NY. Incidence of nasal trauma associated with nasal prong versus nasal mask during continuous positive airway pressure treatment in very low birthweight infants: a randomised control study. *Arch Dis Child Fetal Neonatal Ed*. 2005;90:F480-F483.
27. Robertson NJ, McCarthy LS, Hamilton PA, Moss AL. Nasal deformities resulting from flow driver continuous positive airway pressure. *Arch Dis Child Fetal Neonatal Ed*. 1996;75:F209-F212.
28. Fox MD. Wound care in the neonatal intensive care unit. *Neonatal Netw*. 2011;30:291-303.
29. Aly H, Mohamed MA. An experience with a bubble CPAP bundle: is chronic lung disease preventable? *Pediatr Res*. 2020;88: 444-450.