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Effects of Nasal Continuous Positive Airway Pressure and Cannula Use in the Neonatal Intensive Care Unit Setting

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Abstract

Objective—To investigate the effects of nasal continuous positive airway pressure (CPAP) and cannula use in the neonatal intensive care unit.

Design—Cross-sectional study.

Setting—Tertiary care children's hospital.

Patients—One hundred patients (200 nasal cavities), younger than 1 year, who received at least 7 days of nasal CPAP (n = 91) or cannula supplementation (n = 9) in the neonatal intensive care unit.

Interventions—External nasal examination and anterior nasal endoscopy with photographic documentation.

Main Outcome Measures—The incidence and characteristics of internal and external nasal findings of patients with nasal CPAP or cannula use.

Results—Nasal complications were seen in 12 of the 91 patients (13.2%) with at least 7 days of nasal CPAP exposure, while no complications were seen in the 9 patients with nasal cannula use alone. The external nasal finding of columellar necrosis, seen in 5 patients (5.5%), occurred as early as 10 days after nasal CPAP use. Incidence of intranasal findings attributed to CPAP use, in the 182 nostrils examined, included ulceration in 6 nasal cavities (3.3%), granulation in 3 nasal cavities (1.6%), and vestibular stenosis in 4 nasal cavities (2.2%). Intranasal complications were seen as early as 8 to 9 days after nasal CPAP administration. Nasal complications from CPAP were associated with lower Apgar scores at 1 ($P = .02$) and 5 ($P = .06$) minutes.

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Conclusions—External or internal complications of nasal CPAP can be relatively frequent (13.2%) and can occur early, and patients with lower Apgar scores may be at higher risk. Close surveillance for potential complications should be considered during nasal CPAP use.

Nearly all patients in the neonatal intensive care unit (NICU) require some method of supplemental oxygen administration, such as nasal cannula, nasal continuous positive airway pressure (CPAP), or endotracheal intubation. Nasal CPAP is a good alternative for many neonates. It is frequently used at many pediatric institutions to avoid long-term endotracheal intubation, which may lead to the development of acquired subglottic stenosis. Pediatricians, neonatologists, and pediatric subspecialists are all involved in the care of neonates who are treated with these methods of supplemental oxygen administration.

Growing evidence supports the use of nasal CPAP in the NICU. Nasal CPAP has been shown to effectively reduce morbidity after extubation in premature infants.[1] Other studies have described better clinical outcomes with nasal CPAP when treating bronchiolitis in infants.[2,3] In a retrospective study from British Columbia,[4] the use of nasal CPAP increased from 60% from 1996 to 2000 to 71% from 2000 to 2004; a simultaneous significant reduction was seen in the need for corticosteroids, surfactant, and mechanical ventilation during those periods. Short binasal prong devices appear to be the most effective delivery mechanism,[5] and nasal CPAP use has been found to result in more successful extubations of preterm infants.[4,6] At our institution, we have seen the same trend of nasal CPAP use in our NICU during the past 6 years, rising from 30% to 47% (Figure 1).

A few studies in the literature have linked various CPAP devices to nasal complications.[7–9] While external complications can be easily identified on routine external examination, including using overhead lighting alone, none of these studies have performed endoscopy to investigate the intranasal effects in a potentially obligate nasal-breathing population. After encountering a neonate in our institution with nearly complete bilateral vestibular stenosis after 10 days of nasal CPAP and 37 days of nasal cannula use,[10] we conducted this cross-sectional study to characterize the internal and external nasal effects of using such devices and to determine the incidence of their occurrence.

METHODS

Institutional review board approval and informed parental consent were obtained before enrolling patients in this study. One hundred consecutive, consenting NICU patients (200 nasal cavities) were enrolled in the study from July 25, 2007, through June 30, 2008, at a tertiary care children's hospital. We included patients younger than 1 year with at least 7 days of nasal CPAP or cannula use. We excluded patients with pyriform aperture stenosis, choanal atresia, cleft lip or palate, or previous nasotracheal intubation or nasal surgery. External nasal examinations and anterior nasal endoscopy (0° telescope) with digital photographic documentation were performed on each patient; the indices studied are given in Figure 2. Intranasal findings were recorded. When vestibular stenosis occurred, it was graded as mild (<20%), moderate (20%–50%), or severe (>50%). We used the Fisher exact test to compare differences between CPAP and nasal cannulation and to compare differences between CPAP with and without complications. We used the Wilcoxon rank sum test to compare differences between groups for gestational age, birth weight, and Apgar score at 1 and 5 minutes because these observations were not normally distributed. All statistical tests were performed using commercially available software (Stata 10.1; Stata-Corp, College Station, Texas).

RESULTS

In this cross-sectional study, we found intranasal complications associated with nasal CPAP use, including ulceration in 6 of 182 nasal cavities (3.3%), granulation in 3 nasal cavities (1.6%), and vestibular stenosis in 4 nasal cavities (2.2%) (Table 1). Ulceration, granulation, and vestibular stenosis were found as early as 8 to 9 days after administration of nasal CPAP. These findings were all located at the tip of the nasal CPAP prong within the anterior nasal cavity. The primary external complication, columellar necrosis, was found in 5 of 91 patients with nasal CPAP exposure (5.5%); these cases of columellar necrosis occurred after 10 to 25 days of exposure (Table 2). Examples of photographic documentation from this study are shown in Figure 3 and Figure 4. Our study consisted of relatively equal numbers of male (54%) and female (46%) infants. A trend toward lower mean gestational age, birth weight, and Apgar scores was seen in patients who developed nasal CPAP complications (Table 3). No complications were seen in the nasal cannula group.

When we compared the incidence of complications among patients exposed to nasal CPAP (n=91) with those among patients exposed to nasal cannula (n = 9), there was no statistically significant difference (P=.60). When we compared the clinical variables within the nasal cannula group with those of the nasal CPAP group, there were statistically significant differences in gestational age (P=.02), birth weight (P=.03), and Apgar scores (P=.02). When we looked at the groups of nasal CPAP with and without complications, only the Apgar score at 1 minute reached statistical significance (P = .02), and the Apgar score at 5 minutes (P = .06) showed a strong association. There were no statistically significant differences among patients receiving nasal CPAP who developed complications in terms of gestational age, birth weight, CPAP setting, or CPAP duration.

COMMENT

Nasal CPAP is gaining popularity as a preferred means of ventilatory support in the NICU, and its potential complications will be encountered more frequently. To date, there are limited reports in the literature regarding intranasal complications. Loftus and colleagues[11] described 8 patients with nasal deformities attributed to nasal CPAP use, including but not limited to nasal vestibular stenosis. DeRowe et al[12] described a 6-week-old patient with bilateral nasal synechiae after 3 weeks of nasal CPAP use that ultimately required endoscopic synechialysis, bilateral stenting, and repeated dilations.

Similarly, Smith and Roy[13] described 2 cases of vestibular stenosis after the use of nasal CPAP. The first case described was a 4-month-old infant, premature at 26 weeks' gestation, who was found to have bilateral 80% nasal vestibular stenosis and significant cosmetic deformity. A second patient had bilateral 95% nasal vestibular stenosis. Both required surgical correction of the nasal defects.[13]

At our institution, we encountered a case of near-complete bilateral vestibular stenosis in a 7-week-old infant, which prompted this study. This patient received 10 days of nasal CPAP and 37 days of nasal cannula oxygen supplementation. Immediately after birth, nasal catheters were passed without difficulty through both nasal passages. At nearly 7 weeks of age, nasal endoscopy showed bilateral nearly complete (>95%) vestibular stenosis at the tip where the nasal CPAP would have been positioned. Results of computed tomography demonstrated an anterior soft-tissue band that occluded both nasal airways. Nasal repair was successfully performed endoscopically with lysis, application of mitomycin, and nasal stenting.[10] Treatment strategies that have been reported for repair of nasal vestibular stenosis are auricular composite grafting,[14,15] full-thickness skin grafting with pyriform aperture enlargement,[16] vestibular labial mucosal grafting,[17] or fitting the patient with a custom-made vestibular device after surgical repair.[18]

The development of iatrogenic nasal vestibular stenosis has been thought to result from disruption of the nasal vestibular lining, with resultant proliferation of granulation and fibrous tissue.[13] We also believe that the development of nasal vestibular stenosis from nasal CPAP occurs in a stepwise fashion. A CPAP model for vestibular stenosis formation could involve pressure necrosis from the nasal prongs, air trauma itself, or bacterial contamination with stasis at the prong-mucosal interface, similar to the previously described mechanisms of traumatic subglottic stenosis.[19] This initial trauma may lead to ulceration and induce a second phase of reactive granulation tissue formation. Finally, the granulation tissue can form a mature scar resulting in vestibular stenosis; however, further studies of examinations of the nasal cavities before, during, and after CPAP placement would need to be performed to elucidate this. In the literature, vestibular stenosis has been described as a result of previous nasal surgical procedures,[15,16] nasal packing,[15] excessive cauterization for epistaxis,[20] birth trauma,[21] and flash burn injury.[22] There were no complications that could be attributed to temperature malfunctioning on the vaporizer used with nasal CPAP in our series. Frequent traumatic suctioning of the nares could also exacerbate the nasal mucosal injury caused by the nasal CPAP. Congenital cases of nasal pyriform aperture stenosis, a different embryologic entity, have been described[23,24]; however, nasal vestibular stenosis is an acquired process.

Although this was an observational and cross-sectional study, not powered to reach statistical significance, it showed a trend toward intranasal complications in patients with lower mean birth weight, gestational age, and Apgar scores. Neonates with these characteristics may be at increased risk for multiple reasons, including the smaller size of the columella and inferior turbinate, the decreased cross-sectional area of the external nasal valve, the immaturity of the skin and nasal structures, and likely the more frequent need for CPAP use (compared with nasal cannula). Although there were no abnormal findings in the nasal cannula group, a larger number of patients would be needed to reach statistical significance. Our primary objective in this cross-sectional study of 100 patients was to characterize and determine the incidence of complications rather than to contrast nasal cannula with nasal CPAP. The nasal CPAP duration and settings were not predictive factors in this study. The statistically significant findings of lower gestational age, lower birth weight, and lower Apgar scores in patients requiring nasal CPAP compared with nasal cannula reinforced that patients with these characteristics are more likely to need additional respiratory support (ie, nasal CPAP).

External complications from nasal CPAP (ie, columellar necrosis) can be easily identified on routine physical examination. We found that 5.5% of our patients exposed to nasal CPAP had evidence of varying degrees of columellar necrosis. Once this occurs, it is difficult to repair surgically, and adverse cosmetic results may ensue. In our series, columellar necrosis was found as early as 10 days after placement of nasal CPAP, but columellar necrosis has been reported as early as after only 3 days of nasal CPAP use in very-low-birthweight infants.[25] This complication can be easily prevented by frequent monitoring of the columella during nasal CPAP use. In the NICU setting, attempts should be made to prevent such nasal trauma, including the application of additional dressings for skin protection, periodic inspection with movement of the prongs for improved tissue perfusion, and alternative CPAP prongs or mask devices when indicated.

CONCLUSIONS

To our knowledge, this is the first study to use nasal endoscopy to characterize and determine the incidence of intranasal complications caused by nasal CPAP use in the NICU. We found an overall internal or external complication rate of 13.2%. Frequent examinations of the columella must be performed on neonates using nasal CPAP because necrosis was

found as early as 10 days after administration. Although complications may not warrant surgical intervention in most cases, we found intranasal ulceration, granulation, and vestibular stenosis in our NICU. Vestibular stenosis occurred as early as 8 days after nasal CPAP placement. Lower Apgar scores were a stronger predictor of the development of intranasal complications. A trend toward lower average gestational age and birth weight was found in patients who developed complications. Nasal cannula use alone was not associated with any complications. Nasal CPAP has become an important method of oxygen supplementation in the NICU setting, and health care providers must be aware of the potential complications.

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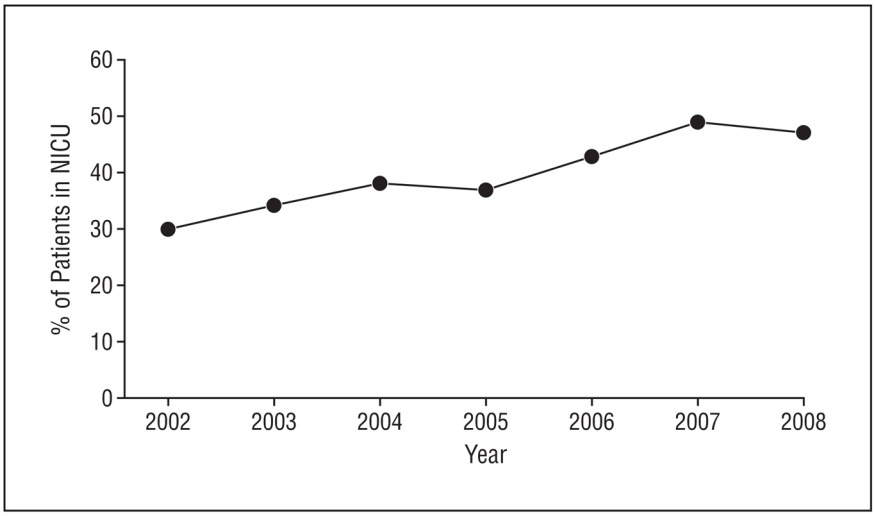

Figure 1.
Internal review of the neonatal intensive care unit (NICU) at our institution. An increasing trend in the frequency of nasal continuous positive airway pressure (CPAP) use among patients in the NICU is seen from 2002 to 2008.

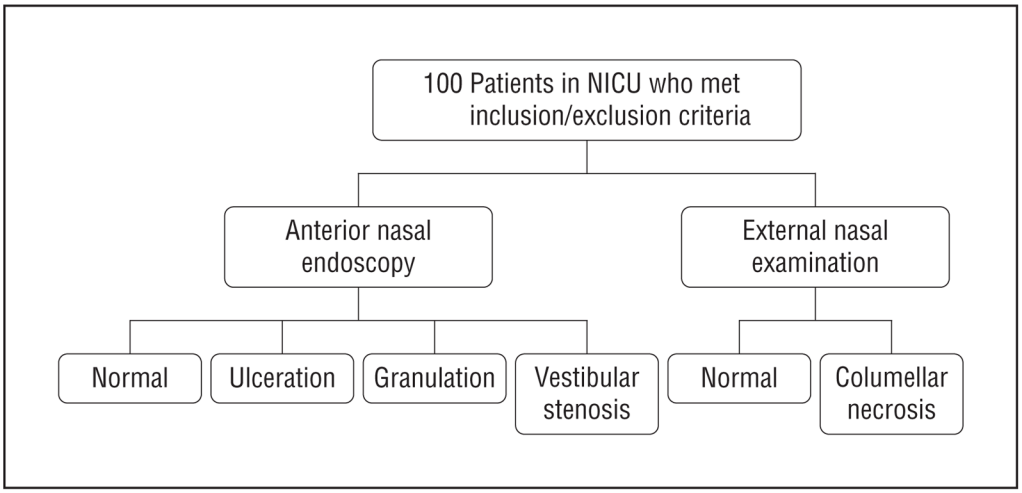

Figure 2.
Cross-sectional study design. NICU indicates neonatal intensive care unit.

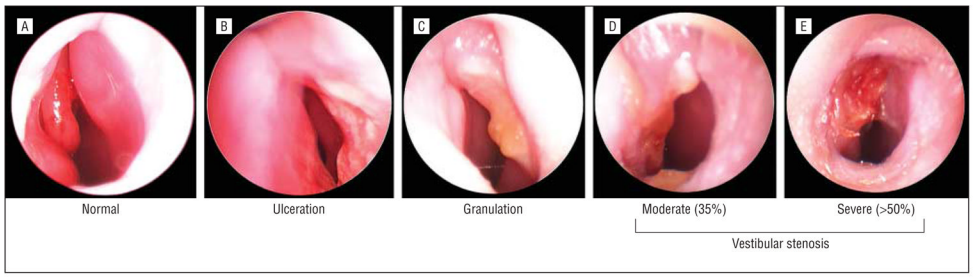

Figure 3.
Anterior nasal endoscopy images demonstrate normal findings (A), ulceration (B), granulation (C), and vestibular stenosis (D and E).

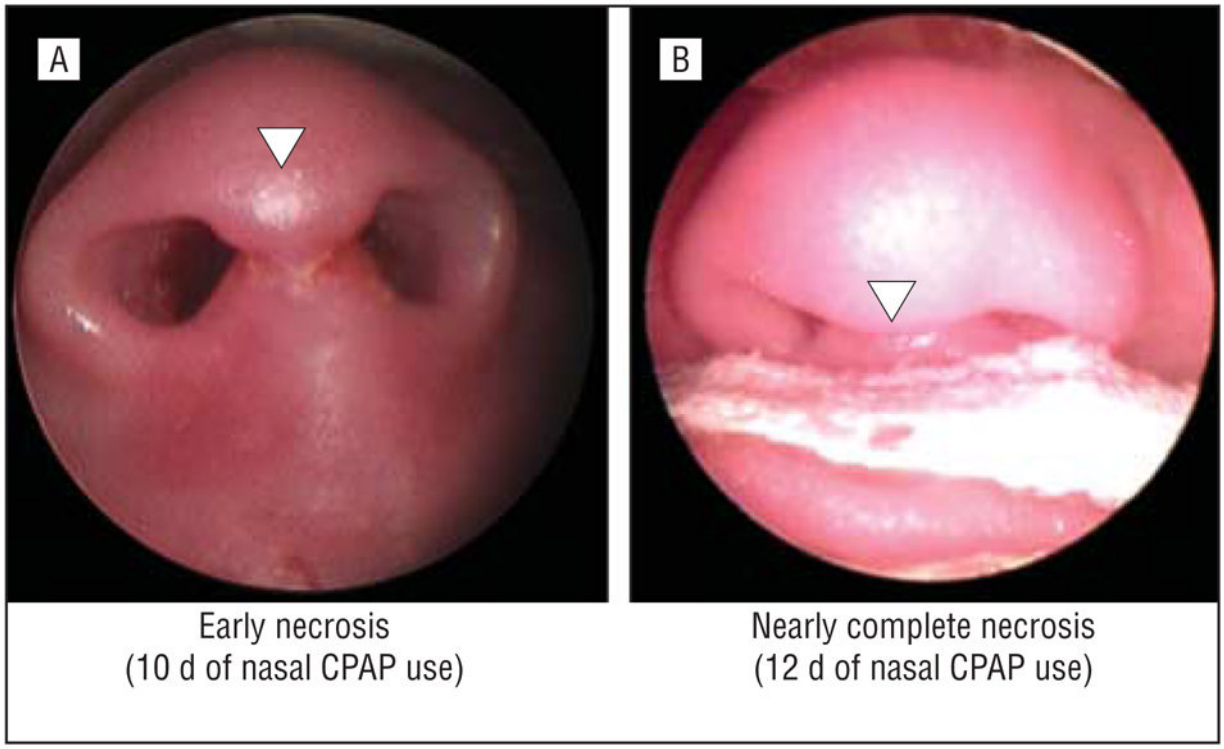

Figure 4.
External nasal examination images demonstrate early (A) and late (B) columellar necrosis (arrowheads). The necrosis occurred 10 and 12 days after initiation of nasal continuous positive airway pressure use.

Table 1

Intranasal Complications Associated With Nasal CPAP

Variable	Nasal Cannula Group (n=18)	Nasal CPAP Group (n=182)
Incidence of nasal cavities with complication, No. (%)[a]		
Ulceration	0	6 (3.3)
Granulation	0	3 (1.6)
Vestibular stenosis	0	4 (2.2)
Duration of supplemental oxygen use associated with complications, range, d		
Ulceration	…	8–36
Granulation	…	9–60
Vestibular stenosis	…	8–20

Abbreviations: CPAP, continuous positive airway pressure; ellipses, not applicable.

[a] Incidence is calculated by using the number of nasal cavities in the group as the denominator.

Table 2

Incidence of Columellar Necrosis

Variable	Nasal Cannula Group (n=9)	Nasal CPAP Group (n=91)
Incidence of patients with columellar necrosis, No. (%)[a]	0	5 (5.5)
Duration of supplemental oxygen use associated with columellar necrosis, range, d	…	10–25

Abbreviations: CPAP, continuous positive airway pressure; ellipses, not applicable.

[a] Incidence is calculated using the number of patients in the group as the denominator.

Table 3

Clinical Characteristics of Patients Receiving Supplemental Oxygen

Characteristic	Nasal Cannula Group[a] (n = 9)	Nasal CPAP Group		*P* Value	
		No Complications (n = 79)	With Complications (n = 12)	Cannula vs CPAP Group	CPAP Groups With vs Without Complications
Mean gestational age, wk	32.9	28.2	27.0	.02	.54
Mean birth weight, g	1945	1221	1010	.03	.93
Mean Apgar score					
1 min	6.11	4.15	2.67	.02	.02
5 min	7.44	6.23	4.83	.02	.06
Mean CPAP duration, d	…	19.4	19.5	…	…
Mean CPAP setting, cm H_2O	…	7.08	7.08	…	…

Abbreviations: CPAP, continuous positive airway pressure; ellipses, not applicable.

[a]No complications were seen among these patients.