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Brief Report

Post-acute day and night non-invasive respiratory intervention use and outcome: A brief report

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Abstract.
OBJECTIVE: This study aimed to describe daytime and nighttime use and outcome of non-invasive respiratory intervention (NIRI) for infants born prematurely and for children with medical complexity (CMC) during a post-acute care hospital (PACH) admission.
METHODS: Thirty-eight initial PACH admissions (October 2018 through September 2020) for premature infants (< 1 year; $n = 19$) and CMC (> 1 year; $n = 19$) requiring NIRI during the day and/or at night were retrospectively examined. Measures included: 1) daytime and nighttime NIRI use by type (supplemental oxygen therapy via low-flow nasal cannula or positive airway pressure [PAP] via high-flow nasal cannula, continuous positive airway pressure, or biphasic positive airway pressure at admission and discharge) and 2) daytime and nighttime NIRI outcome—reduction, increase, or no change from admission to discharge.
RESULTS: For the total sample ($n = 38$), daytime vs nighttime NIRI use was significantly different ($p < 0.001$). At both admission and discharge, supplemental oxygen was the most common NIRI during the day, while PAP was most common at night. From admission to discharge, seven (18%) infants and children had a positive change (reduced NIRI) during the day, while nine (24%) had a positive change at night. At discharge, 11/38 (29%) infants and children required no daytime NIRI, while 4/38 (11%) required no day or night NIRI.
CONCLUSION: NIRI use differs between day and night at PACH admission and discharge for CMC. Reductions in NIRI were achieved during the day and at night from PACH admission to discharge for both infants born prematurely and for children with varied congenital, neurological, or cardiac diagnoses.

Keywords: Noninvasive ventilation; oxygen; infant; child; post-acute care; hospital

1. Introduction

Non-invasive respiratory intervention (NIRI) use has expanded across care settings for infants born prematurely [1] and children with medical complexity (CMC) of all ages [2–4]. This increase has been driven by technology improvements, availability, safety, cost, and the growing acceptance of NIRI as an effective intervention in pediatric complex care [2, 5]. Similar to invasive mechanical ventilation via tracheostomy, the purpose of NIRI is to support or enhance the respiratory central drive, assist weak

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respiratory musculature, and/or decrease the respiratory load due to obstruction or restriction and, thus, improve inadequate gas exchange. The benefits of NIRI compared to invasive ventilation may include improved quality of life, reduced morbidity, and reduced health care costs [6].

NIRI type, interface, and delivery device are chosen based on age and intended purpose [6, 7]. The least restrictive NIRI type, low-flow oxygen via nasal cannula (NC), has been described as oxygen flow of 0.5–1 L/min for infants and <2 L/min for older children. Alternatively, oxygen via high-flow NC for children supplies humidified and heated air/oxygen via NC at rates > 2 L/kg and has been purported to provide some amount of positive pressure [8]. Continuous positive airway pressure (CPAP) and biphasic positive airway pressure (BiPAP) are most supportive, delivering positive pressure with or without supplemental oxygen. CPAP provides constant positive pressure throughout the entire respiratory cycle, preventing airway closure, while BiPAP delivers a pre-set positive pressure at inspiration as well as positive end expiratory pressure, improving ventilation and gas exchange more effectively than CPAP by increasing tidal volume as well as functional residual capacity [9].

Long-term NIRI dependence is defined as use for longer than three months [5, 10], as often seen with infants born prematurely and CMC admitted to pediatric post-acute care hospitals (PACHs). When infants and children who require NIRI are admitted to a PACH, it is typically after NIRI was initiated at a referring acute care hospital. The goals of a PACH admission for infants born prematurely and CMC requiring NIRI may include weaning or acclimation for home use [11]. There are, however, limited outcome data [4, 10–12] and no known reports of daytime vs nighttime use for either diagnostic group. The purpose of this study was to describe daytime and nighttime use and outcome of NIRI for infants born prematurely and CMC during initial PACH admission.

2. Methods

2.1. Setting

This retrospective examination of NIRI dependence among infants born prematurely and CMC was conducted at one pediatric PACH in the northeastern United States. The objectives of a PACH admission are to foster medical stabilization, optimize respiratory intervention, maximize development and function, promote optimal nutrition, and educate caregivers. Children are managed by pediatricians and nurse practitioners, while pulmonologists consult daily regarding NIRI type and settings. Additional PACH service providers include physiatrists; respiratory, physical, occupational, and speech therapists; dietitians; child life specialists; social workers; and case managers.

2.2. Subjects and procedures

Following Institutional Review Board approval, infants and children admitted for the first time from October 2018 through September 2020 and dependent on NIRI during the day and/or at night were identified. Those who required invasive respiratory intervention via a tracheostomy were excluded. Demographics were extracted from the electronic medical record system, including admitting diagnosis and up to 10 additional diagnoses, date of birth, reason for admission, admission date, discharge date, and discharge disposition. Due to the complexity of patients' clinical profiles, the admitting diagnosis was assigned to a previously reported diagnostic category for pediatric post-acute care (prematurity, multiple congenital anomalies [MCA], neurological/neuromuscular, cardiac) [13]. The four categories were further collapsed to two diagnostic groups (premature infants [<1 year chronological age] and CMC [>1 year of age]). Reason for admission was coded as 'Respiratory' or 'Non-respiratory.' Admission age and length of stay (LOS) were calculated for each child.

NIRI type for daytime and nighttime use at admission and discharge were recorded as follows: 0 = no intervention/room air; 1 = supplemental oxygen therapy (oxygen via low-flow NC); 2 = positive airway pressure (PAP; oxygen via high-flow NC, BiPAP, or CPAP). Daytime and nighttime were defined as 12-hour periods during a 24-hour timeframe and coded separately.

2.3. Analysis

Data analysis was performed using the IBM Statistical Package for the Social Sciences (SPSS), Version 22 (IBM SPSS Statistics, IBM Corporation). Descriptive statistics were used to quantify demographics for the total sample and for the two diagnostic groups. A *t*-test was used to compare mean age and LOS, and a chi-square statistic was used to assess differences in reason for admission and discharge disposition between diagnostic groups.

For the total sample and both diagnostic groups, the frequency distribution for day vs night NIRI type (n, %) at admission and discharge was calculated (Table 2). Comparisons between daytime and nighttime NIRI type at admission and discharge were analyzed using the non-parametric Wilcoxon signed-rank test for the total sample. Statistical significance was accepted at $p < 0.05$.

NIRI outcome was defined as change in NIRI type between admission and discharge. It was calculated by ranking NIRI by level of support (0 = no NIRI; 1 = oxygen via low-flow NC, 2 = high-flow oxygen via NC, 3 = CPAP, or 4 = BiPAP) and computing the difference from admission to discharge for both day and night. Three outcome groups represented change in NIRI type at discharge for day and night: 1) negative change (increase in NIRI support; e.g., low-flow oxygen to high-flow oxygen); 2) no change (same NIRI type at admission and discharge), and 3) positive change (reduced or no NIRI at discharge). Frequencies for each outcome group were calculated for the total sample and by diagnostic group for both daytime and nighttime use.

3. Results

Between October 2018 and September 2020, 38 infants and children (total sample mean age = 3.64 years, SD = 5.29, range = 0.13–21.52) in two diagnostic groups (premature infants [n = 19, 50%] and CMC [n = 19, 50%]) were admitted to the PACH. Diagnostic categories for CMC were MCA (n = 10, 26%), neurological/neuromuscular (n = 8, 21%) and cardiac (n = 1, 3%). Table 1 provides demographics for the total sample and by group. Differences between diagnostic groups were significant ($p < 0.001$) for admission age and reason for admission ($p = 0.034$).

For the total sample, daytime vs nighttime NIRI use by type differed at admission ($z = -3.39$, $p = 0.001$) and discharge ($z = -3.45$, $p = 0.001$). At admission, the most common daytime type of NIRI used was oxygen via low-flow NC (n = 23, 44%) and at night was PAP (n = 20, 53%). Similarly, at discharge, the most common daytime NIRI type was oxygen via low-flow NC (n = 20, 53%) and PAP at night (n = 18, 47%). Eight (21%) required no daytime NIRI at admission, while at discharge, 11 (29%) required no

Table 1

Demographics for the total sample (n = 38) and by diagnostic group

	Mean (SD) admission age (years)*	Reason for PACH admission**		Discharge disposition+				Mean (SD) length of stay+ (days)
		Respiratory	Non-respiratory	Home	Planned transfer	Unplanned transfer	Deceased	
Premature infants (n = 19)	0.41 (0.16)	19	0	12	4	3	0	51.26 (34.33)
Children with medical complexity (n = 19)	6.87 (5.91)	15	4	8	4	6	1	64.26 (55.01)
Total sample	3.64 (5.27)	34 (90%)	4 (10%)	20 (53%)	8 (21%)	9 (24%)	1 (3%)	57.76 (45.70)

*$p < 0.001$; **$p = 0.034$; +1st PACH admission. SD – standard deviation; PACH – post-acute care hospital.

daytime NIRI. All 38 (100%) required NIRI at night on admission, while only 34 (79%) required NIRI at night at discharge (Table 2).

During the day, seven (18%; premature infants $n = 5$, CMC $n = 2$) had a positive change (reduced support), while four (11%; premature infants $n = 2$, CMC $n = 2$) had a negative change (increased support). Twenty-seven of 38 (71%) had no change in daytime NIRI from admission to discharge. At night, nine (24%; premature infants $n = 5$, CMC $n = 3$) had a positive change, and four (10%; premature infants $n = 2$, CMC $n = 2$) had a negative change. Twenty-five (66%) had no change in nighttime NIRI from admission to discharge.

4. Discussion

NIRI has become a preferred intervention for premature infants and CMC with respiratory insufficiency as well as sleep and breathing disorders [3, 14]. This is the first known study to examine daytime and nighttime NIRI use and outcome. In this study, daytime vs nighttime use and outcomes were chosen specifically for examination, as it was hypothesized based on experience that infants and children would have different needs during these time periods with more support required at night.

In this PACH, reduced NIRI is attempted incrementally by the respiratory therapist when the patient's oxygen saturation is sustained at $\geq 97\%$ over four or more hours. Reducing NIRI during the day is typically attempted first, though weaning from NIRI is not always a goal for PACH admission. Admission goals may include acclimation to NIRI, caregiver education for NIRI home use, or change to a more supportive NIRI type due to primary diagnosis [10, 11]. These results are consistent with conclusions from a multi-institutional analysis of NIRI outcome among infants, citing positive changes in non-invasive support parameters and/or discontinuation of NIRI for infants with airway disorders rather than neuromuscular diseases [15]. As anticipated, no children with neuromuscular disorders in this study weaned to a lower level of support during admission.

It is common for infants and children to have multiple admissions to the PACH and transfer back to an acute care hospital emergently or for a scheduled procedure [16, 17]. Having examined data for initial admissions only, the ultimate discharge disposition and NIRI outcome may be different from what is

Table 2

Day vs night non-invasive respiratory intervention use by type at admission and discharge

		Daytime			Nighttime		
		Room air	Supplemental oxygen	PAP	Room air	Supplemental oxygen	PAP
Admission	Premature infants ($n = 19$)	2	11	6	0	10	9
	CMC ($n = 19$)	6	12	1	0	8	11
	Total	8	23	7	0	18	20
Discharge	Premature infants ($n = 19$)	4	10	5	2	11	6
	CMC ($n = 19$)	7	10	2	2	5	12
	Total	11	20	7	4	16	18

PAP – positive airway pressure; CMC – children with medical complexity.

reported here. Outcomes were also limited by NIRI interface, as no children are discharged home with high-flow oxygen as no equipment is available for home use. CPAP and BiPAP delivered via a home-use mechanical ventilator requires children to weigh more than 5 kilograms, limiting use for infants. In addition, a nasal or facial mask is required, and due to the functional limitations of CMC, use of a mask increases the risk of aspiration with vomiting. Mask leakage and skin breakdown are also often barriers to tolerance and success [3, 5, 7].

While this sample was small, heterogeneous by age and diagnosis, and limited to one facility, this study provides data to examine day vs night use. It is suggested that any reduction in support is a positive outcome, even if limited only to daytime or nighttime. Reduced NIRI may allow for discharge home, school attendance, reduced caregiver training needs, minimized family burden, and ultimately, quality of life improvement. Future studies could include daytime and nighttime NIRI use and outcome by age, by diagnosis, and in additional care settings. Lastly, the examination of weaning methods and protocols for NIRI for children in post-acute care is warranted.

5. Conclusion

NIRI use by type differs between day and night at initial PACH admission and discharge. Reductions in NIRI support can be achieved during the day and at night from admission to discharge for premature infants and for CMC.

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Conflict of interest

The authors have no conflict of interest to report.

Ethical considerations

The Institutional Review Board at Franciscan Children's Hospital, Brighton, MA, (Franciscan Hosp for Children #1, IRB00004138) reviewed and approved this study in October 2020.

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