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Original Research

Efficacy and Safety of Nasal High-Flow Therapy for Neonatal Transport

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A B S T R A C T

Objective: Noninvasive ventilation, including nasal high-flow therapy (nHFT), provides effective neonatal respiratory support. There are limited data on nHFT use during neonatal transport. Our objective was to assess the efficacy and safety of nHFT during neonatal transport.

Methods: One hundred ninety-five neonates transported on nHFT via a Neo-Pod "T" system (Westmed Inc, Tucson, AZ) were identified from Life Flight transport data. Data included demographics, transport location, distance, indication, and mode as well as pretransport and intratransport respiratory support data. We compared neonates who successfully tolerated nHFT transport with those who required support escalation (defined as increase in flow ≥2 L/min or fraction of inspired oxygen [FiO_2] ≥20%).

Results: Eighty-seven percent of neonates (170/195) were effectively transported on nHFT. Infants requiring escalation of nHFT support had a significantly higher pretransport FiO_2 (median = 0.60 [interquartile range, 0.36-1.00] vs. 0.36 [0.23-0.56]; $P < .05$) and a longer ground time for stabilization (56 ± 25 vs. 39 ± 18 minutes, $P < .05$) and were more frequently transported by air.

Conclusion: Nasal HFT can be an effective mode of respiratory support in the transport of selected neonates. FiO_2 at the time of transport may be a key parameter to aid in determining neonates who can be safely transported on nHFT.

Noninvasive modes of ventilation (NIV) can safely and effectively provide neonatal respiratory support.[1] NIV is preferable to intubation and mechanical ventilation because it reduces the risk of ventilator-induced lung injury.[2] For many years, continuous positive airway pressure (CPAP) has been the most common mode of neonatal NIV.[1] In recent years, nasal high-flow therapy (nHFT) has been introduced as an alternative option for providing neonatal noninvasive respiratory support, and the use of nHFT continues to steadily increase.[3-5] nHFT has become the preferred primary mode of respiratory support postextubation and is preferred by care providers over CPAP for a variety of reasons including neonatal comfort and ease of access for care.[5]

Neonates with respiratory dysfunction often need to be transported within or between hospitals. Studies have shown the efficacy and safety of CPAP for the transport of neonates.[6-9] Less is known about the use of nHFT for respiratory support during the transport of neonates. Recently, nHFT has been used more frequently for the transport of neonates, but there are few studies to date describing the efficacy and safety profile of nHFT. The report by Schlapbach et al[10] identified 150 infants less than 2 years of age with a mean age of 6 months transported by nHFT. They documented a significant decrease in intubation associated with the introduction of nHFT to their transport service. Boyle et al[11] reported the safe transport of a small cohort of preterm infants within Eastern England. They suggested that infants weighing greater than 1,200 g requiring flow of less than or equal to 6 L/min could be transported successfully via nHFT. Since 2011, our Life Flight neonatal team has been transporting neonates with nHFT. The purpose of this study was to assess the safety and efficacy of nHFT during neonatal transport within our system and to identify characteristics of neonates most likely to be successfully transported via nHFT.

Methods

After institutional review board approval, we performed a retrospective review of all neonates transported on nHFT by the Intermountain Healthcare Life Flight neonatal transport team during the years 2012 to 2013. The Life Flight program is 1 of the largest

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neonatal transport programs in the Intermountain Region, performing approximately 1,000 neonatal transports per year by helicopter, airplane, or ground ambulance. Dedicated registered nurse (RN)/RN teams are positioned at 2 bases, and an additional 2 bases support on-call RN/RN or RN/respiratory therapist teams. Most team members have 15 to 25 years of transport experience. We chose this 2-year period because it followed a 1-year period of full implementation and refinement of the neonatal nHFT transport protocol introduced in 2011 and preceded the introduction of disparate electronic medical record systems between the transport system and the hospital. Per the nHFT protocol, neonates were chosen by the team for transport with nHFT if they had no or mild respiratory distress on nasal cannula low > 1 L/min and ≤ 6 L/min or if they had no signs of distress on nasal CPAP (nCPAP) at ≤ 6 cm H_2O and ≤ 30% fraction of inspired oxygen (FiO_2).

Contraindications to neonatal transport by nHFT include abdominal distention, current apnea, and diagnosis of diaphragmatic hernia. There were no gestational age or weight criteria limiting transport on nHFT. Neonates were excluded if they did not meet the previously described criteria for the initiation of nHFT or if they required intubation before transport. Written Life Flight records of all neonates transported via nHFT over the defined time period were independently reviewed for data collection by 1 of 2 authors (B.M. or G.H.) using standardized data forms. A variety of demographic data were collected, including gestational age, birth weight, weight at time of transport, primary diagnosis, transport time, and mode of transport. Pre-, intra-, and posttransport respiratory support data were also collected. The transport time was assessed, beginning at the time of arrival of the transport team at the referring institution, and ending at the time of drop-off at the accepting institution. Peripheral capillary oxygen saturation (SpO_2)/FiO_2 ratios were calculated for all neonates as a marker of oxygenation.[12] Transcutaneous CO_2 is routinely monitored during transport and was evaluated as a marker of ventilation.[13]

Intermountain Life Flight transport service uses the Neo-Pod "T" (Westmed Inc, Tucson, AZ) circuit and heater to deliver heated humidification during the transport of patients on nHFT. The circuit contains a LavaBed "T" (Westmed Inc, Tucson, AZ) humidifier cartridge, oxygen supply tubing, expandable tubing with a 40-cm pop-off valve and temperature port, and a syringe and tubing for sterile water instillation (Fig. 1). Twenty milliliters of sterile water is initially added to the humidifier cartridge; it is then connected to the heater set at 38°C and connected to a high-flow cannula appropriately sized for the patient. The heater cable and temperature monitor are hardwired into the incubator, and a bracket helps maintain the humidifier in a stable upright position. Additional sterile water is added as needed for longer transports.

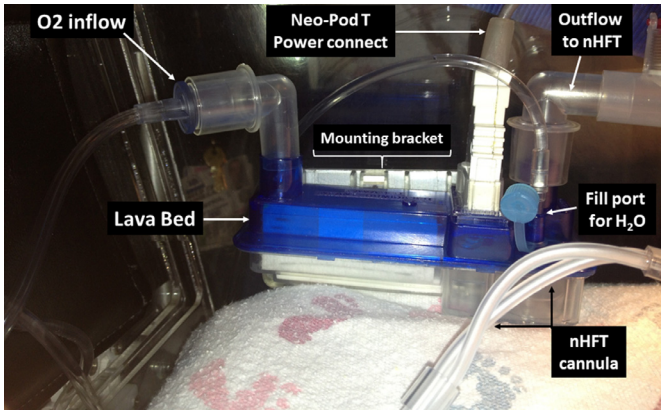

Figure 1. Fully instrumented LavaBed "T" humidification chamber attached to a bracket in a neonatal transport incubator.

We defined the primary outcome of "successful transport" as a neonate remaining on nHFT for the duration of transport without requiring 1) an increase in flow rate of ≥2 L/min above the starting flow rate and/or 2) an increase in FiO_2 of ≥0.20 above the starting FiO_2. For example, a neonate started on nHFT 4 L/min and FiO_2 0.30 had to remain below a flow rate of 6 L/min and below FiO_2 of 0.50 in order to be called "successful." Neonates who met criteria for successful transport were compared with those who required escalation during transport in an effort to identify clinical variables predicting the success or failure of nHFT during neonatal transport. Between groups, continuous variables were analyzed by the *t* test or Mann-Whitney *U* test, whereas categoric variables were assessed via the chi-square or Fisher exact test. The paired sample *t* test or analysis of variance was used to compare nHFT support and respiratory variables within groups before, during, and at the end of transport. Results were considered significant at $P < .05$. We used regression analysis techniques to analyze neonatal and support factors associated with successful transport via nHFT. Because this was a descriptive study, a power analysis was not performed.

Results

During the 2-year period from 2012 to 2013, we identified 197 neonates transported on nHFT per the defined criteria; 2 charts were illegible. Thus, a total of 195 neonates were included in the data set. Of these patients, 87% (170/195) were successfully transported. Characteristics of these neonates and the transport are shown in Table 1 by the success of nHFT or the need for escalation of respiratory support. Notably, 16% (n = 32) of these neonates were less than 30 weeks' gestation, and 12% (n = 23) weighed less than 1,500 g at transport. The mean time for transport was 93 minutes. The median transport distance was 17 miles with 148 (76%) neonates transported less than 60 miles and a maximum transport distance of 259 miles.

Among those neonates who required escalation of respiratory support (n = 25), 76% required an increase in FiO_2, flow, or both. Six infants (3% of the total study population) failed nHFT and required a change in the mode of respiratory support; 5 were intubated (2.6% of the total study population), and 1 was managed on nCPAP.

Table 1
Demographic Information

	Success (n = 170)	Escalation (n = 25)
Gestation at birth (weeks)	35.5 ± 4.1	35.5 ± 3.4
Birth weight (kg)	2.60 ± 0.89	2.80 ± 0.75
Transport weight (kg)	2.72 ± 0.85	3.02 ± 0.88
Age, n (%)_		
< 48 hours (n = 136)	117 (69)	19 (76)
2-21 days (n = 31)	27 (16)	4 (16)
> 21 days (n = 28)	26 (15)	2 (8)
Transport time—all (minutes)	90 ± 37	117 ± 44[a]
Ground time	39 ± 18	56 ± 25[a]
Travel time	50 ± 32	61 ± 37
Primary diagnosis at transport, n (%)		
Respiratory (n = 108)	92 (64)	16 (64)
Cardiac (n = 23)	21 (12)	2 (8)
Congenital anomaly (n = 17)	15 (9)	2 (8)
Other (n = 47)	42 (25)	5 (20)
Respiratory support before transport, n (%)		
NC (n = 58)	49 (29)	9 (36)
nHFT (n = 89)	80 (47)	9 (36)
CPAP (n = 48)	41 (24)	7 (28)
Mode of transport, n (%)		
Intrahospital (n = 26)	24 (14)	2 (8)
Ground (n = 99)	89 (52)	10 (40)
Fixed wing (n = 26)	24 (14)	2 (8)
Rotor wing (n = 44)	33 (19)	11 (44)[a]

CPAP = continuous positive airway pressure; nHFT = nasal high-flow therapy; NC = nasal cannula.
[a] $P < .05$.

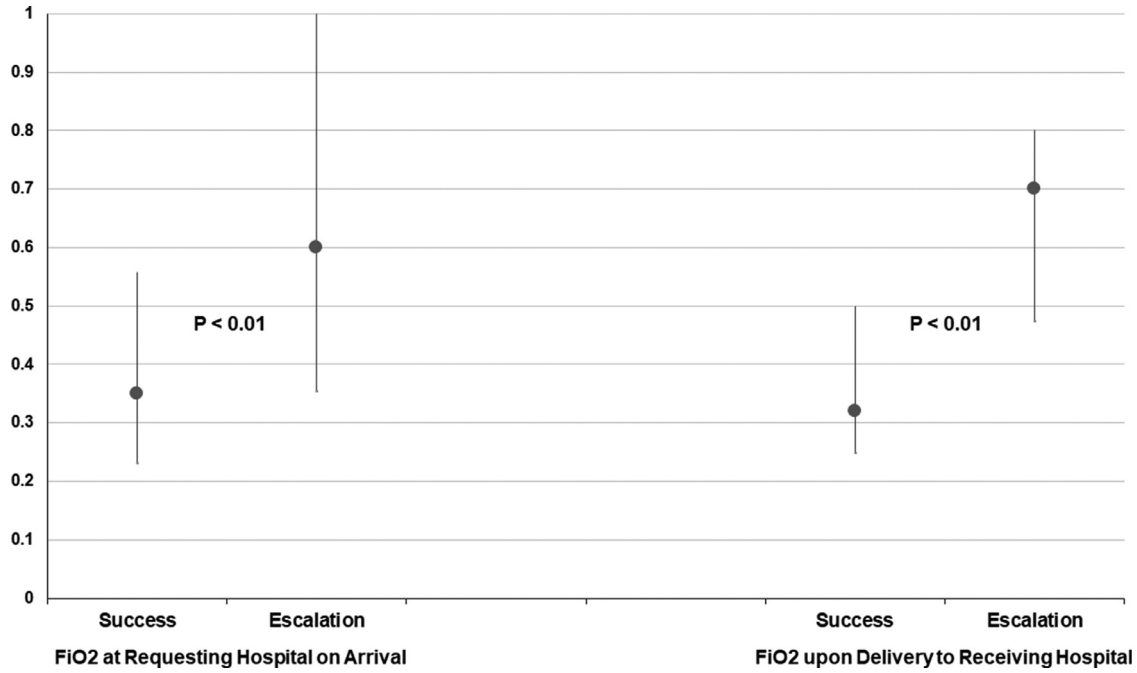

Figure 2. The change in FiO_2. FiO_2 support needs were higher at pretransport and upon delivery for infants requiring escalation of nHFT. • = median; line indicates 25%-75%.

The analysis of respiratory parameters showed significant differences in both FiO2 (Fig. 2) and the SpO_2/FiO_2 ratio (Fig. 3) in infants successfully transported on nHFT compared with those requiring escalation. These 2 indices of respiratory support did not change significantly during transport within each group. Infants who required escalation of support had significantly higher gas flow during and at the end of transport (Table 2). There were no differences in the recorded ranges of transcutaneous pCO_2.

A regression analysis showed that the pretransport SpO_2/FiO_2 ratio and ground time were significant risk factors related to the escalation of support. Intubation risk was primarily related to ground time (Table 3).

Discussion

In this study, we found that the majority of neonates were successfully transported on nHFT. Of those who required escalation of respiratory support during transport, most remained on nHFT, and very few required a change in the mode of support to nCPAP or intubation.

There are limited prior studies regarding the transport of neonates on nHFT. A report by Schlapbach and colleagues[10] from Australia reported a significant reduction in pretransport intubations and a reduced need for sedation during transport with nHFT, suggesting that nHFT was well tolerated. Their study population was predominantly infants with a mean age of 6 months. Nonetheless, their results

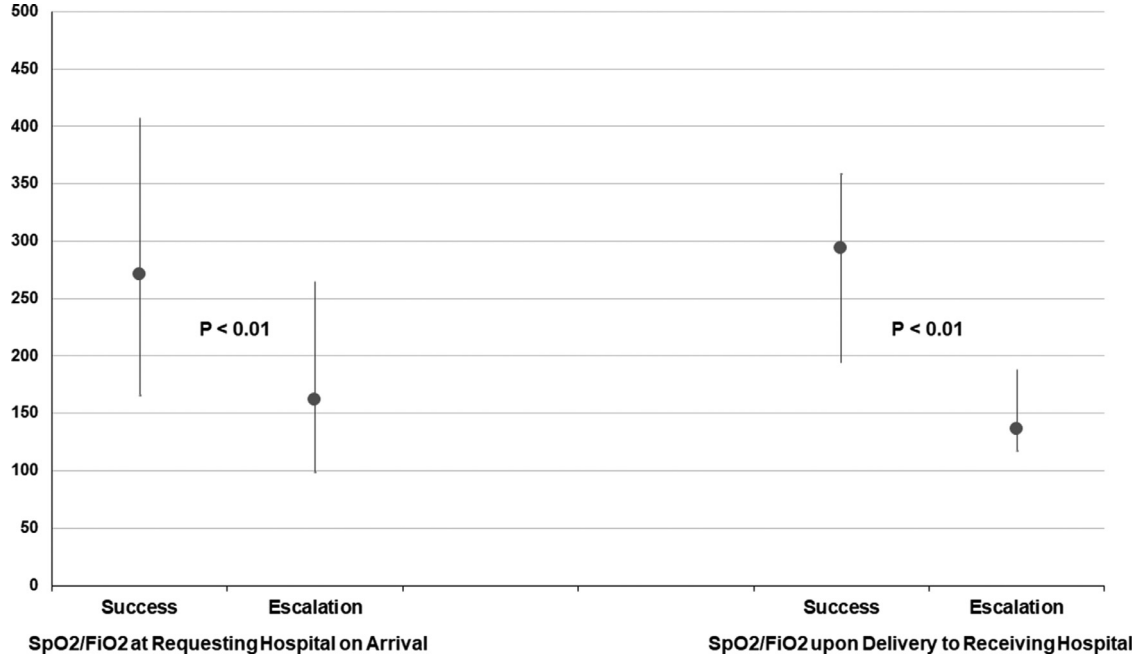

Figure 3. The change in SpO_2/FiO_2. SpO_2/FiO_2 was lower at pretransport and upon delivery for infants requiring escalation of nHFT. • = median; line indicates 25%-75%.

Table 2
Gas Flow and Ventilation During Transport

	Success (n = 170)	Escalation (n = 25)
Nasal cannula flow		
Lowest NC flow	3.7 ± 1.8	3.6 ± 1.2[a]
Highest NC flow	4.0 ± 1.7	4.9 ± 1.3[b]
nHFT flow at drop-off	3.8 ± 1.7	4.8 ± 1.4[b]
TCO_2 during transport		
Lowest recorded	43 ± 7.0	42 ± 7.4
Highest recorded	47 ± 8.0	50 ± 11

nHFT = nasal high-flow therapy; NC = nasal cannula.
[a] $P < .01$ versus "highest."
[b] $P < .01$ versus "success."

Table 3
Risk Factors for Escalation or Intubation

Variable	Odds ratio	95% CI	*P* Value
Escalation of support			
Pretransport SpO_2/FiO_2	0.995	0.991-0.999	0.009
Ground time (minutes)	1.03	1.01-1.05	0.013
Transport mode = rotor	1.68	0.62-4.53	0.306
Intubation			
Pretransport SpO_2/FiO_2	0.998	0.992-1.004	0.538
Ground time (minutes)	1.06	1.02-1.09	0.002
Transport mode = rotor	0.83	0.19-5.29	0.841

CI = confidence interval; FiO_2 = fraction of inspired oxygen; SpO_2 = peripheral capillary oxygen saturation.

were consistent with the findings in our study in that most infants were successfully transported on nHFT, and most of those requiring escalation of support were maintained on nHFT. Boyle et al[11] reported the use of nHFT in the transport of a small cohort of preterm infants in Eastern England. They reported successful transport via nHFT for neonates weighing greater than 1,200 g requiring a flow of less than or equal to 6 L/min without the need for escalation of care.

These findings are similar to ours in that nHFT appeared to be well tolerated during the transport of critically ill neonates without a significant need for escalation of respiratory support. Additionally, our data suggest that neonates most likely to safely tolerate transportation with nHFT may be identifiable by certain characteristics of respiratory requirement before transport. Neonates with lower FiO_2 requirement may be more likely to tolerate transport via nHFT because pretransport FiO_2 was significantly higher in the cohort requiring escalation of care. Neonates who are unlikely to tolerate nHFT might be identifiable by their level of oxygenation before transport because the group that required escalation had a significantly lower SpO_2/FiO_2 ratio. Additionally, neonates who required escalation had a significantly longer ground time before transport, suggesting more time was required to stabilize these neonates before leaving the referring institution. Therefore, a longer ground time required for stabilization may be another important predictor of those who are unlikely to tolerate nHFT. These 3 parameters may be possible criteria in determining the relative risk and safety of transport on nHFT for individual neonates.

Our study is unique in that we included all neonates who met our respiratory criteria regardless of gestational age, birth weight, weight at transport, or diagnosis. Another strength of this study is that we included a relatively large cohort of neonates compared with previous reports. Also, we used a single simple nHFT delivery system with specific recommendations for setup and patient management. The major study limitation is the retrospective nature of the study design with a dependence on paper records. Additionally, although we have a single transport system, different regional neonatal transport teams actively transported neonates on nHFT. There could be some unmeasured variation in practice from the protocol.

In conclusion, we found nHFT was an effective approach to noninvasive respiratory support of neonates during transport. Further studies are needed to compare nHFT with CPAP during transport, to compare different modes/devices for nHFT support, and to develop risk-stratified guidelines to enhance the safety of neonatal transport with nHFT.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2019.04.005.

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