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Prevalence and Predictors of Back-Transport Closer to Maternal Residence After Acute Neonatal Care in a Regional NICU

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Abstract
Objectives To describe the demographics, clinical characteristics and referral patterns of premature infants to a regional level IV neonatal intensive care unit (NICU); to determine the prevalence and predictors of back-transport of infants ≤ 32 weeks gestational age in a level IV NICU; for infants not back-transported closer to maternal residence, determine the length of stay beyond attainment of clinical stability. *Methods* Data (2010–2014) from the Children's Hospital Neonatal Database and individual chart review for infants ≤ 32 weeks admitted to a level IV NICU whose maternal residence was outside the metro area were included. Bivariate associations of maternal and infant characteristics with back-transport were estimated using two-sample *t* tests and Fisher's exact test. Multivariable logistic regression was used to measure independent predictors of back-transport. Clinical stability was defined as the attainment of full volume enteral feedings and low flow nasal cannula. *Results* A total of 223 infants were eligible for analysis; of whom 26% were back-transported after acute care. In the adjusted analysis, insurance status, distance from maternal residence and gestational age were significantly associated with back-transport. For infants not back-transported closer to maternal residence, median length of stay in the level IV NICU beyond attainment of clinical stability was 28.5 days. *Conclusion for Practice* Predictors of back-transport include private insurance, greater distance of maternal residence from NICU and younger gestational age. Many preterm infants admitted to a regional NICU for acute care remained hospitalized in a level IV NICU after achieving clinical stability, for which care in a NICU closer to maternal residence may be appropriate.

Keywords Neonatology · Regionalization of care · Back-transport

Significance

Back-transport (BT) for premature infants is generally safe although its prevalence is highly variable and little is known about the demographic factors that predict BT closer to maternal residence.

This study evaluates the process of BT from a regional level IV neonatal intensive care unit (NICU) with a large referral area. Characteristics of infants who undergo back-transport are evaluated; infants who are younger and those with private insurance are more likely to be back-transported. Infants who are not back-transported remain in a level IV NICU for a significant period of time which represents opportunity for improvement in the BT process.

Introduction

Prematurity affects an estimated 10% of infants born in the United States annually (March of Dimes 2016). Risk appropriate care for premature and high-risk infants, known as regionalization of neonatal care, initially proposed in 1976, has been a focus within neonatology for the past several decades and provides a framework for determining both delivery and neonatal care capabilities (American Academy of Pediatrics Committee on Fetus and Newborn 2012). Levels of neonatal care range from well-baby care in a level I nursery to highly specialized care in a regional IV NICU (American Academy of Pediatrics Committee on Fetus and Newborn 2012). Despite recommendations for pre-delivery maternal transport to higher levels of care, significant numbers of

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premature and low birth weight infants are born at lower levels of care and require escalation of care post-delivery with significant regional variation in practice (Gould et al. 1999; Robles et al. 2017). While there has been research regarding escalation of care for ill neonates, the availability of published data evaluating the process of BT for convalescing infants is sparse and further information regarding this process is essential to develop future guidelines for management of these infants.

Neonatal BT is defined as the return of a previously critically ill infant from a level III or IV NICU to a level II or level I nursery for ongoing care prior to discharge home (American Academy of Pediatrics Committee on Fetus and Newborn 2012). Few studies have evaluated the predictors of back-transported infants and historic literature may not be applicable to current neonatal patient populations as patterns of patient transport and the evolution of neonatal networks and regionalized care have changed over time (Holmstrom and Phibbs 2009; Lynch et al. 1988). The potential benefits of BT include resource savings and less overcrowding of regional NICUs by decreasing the length of stay in a regional NICU beyond clinical stability and improved parental visitation and engagement without noted ill-effects (Jung and Bose 1983; Latva et al. 2007; Zarif et al. 1979).

To address the paucity of data on the prevalence and predictors of BT, the objectives of this study were to (1) describe the demographics, clinical characteristics and referral patterns of premature infants from non-level IV units to a regional level IV NICU, (2) to identify the prevalence and predictors of BT closer to maternal residence at a single institution and (3) for infants not back-transported, determine length of stay beyond clinical stability, defined as attainment of full enteral nasogastric (NG) feedings and low flow nasal cannula (LFNC). We hypothesize that given the lack of guidelines or protocols for BT of preterm infants at this study site, less than half of eligible infants will have been back-transported closer to maternal residence.

Methods

Data Source

Single center data from the Children's Hospital Neonatal Database (CHND) and individual electronic medical records were obtained for analysis. CHND collects prospective data on all infants admitted to participating Children's Hospitals with regional NICUs and currently encompasses 34 regional NICUs throughout the United States and Canada with a level IV designation. Eligibility criteria for participating centers include > 50% outborn population, > 400 annual admissions and > 25 beds (Murthy et al. 2014). Data collected include maternal and pregnancy data and robust clinical and outcomes data from the NICU hospitalization. All infants admitted to the NICU are included in the database. Recurrent admissions for the same infant generate independent records within the database. The characteristics of the infant's hospitalization including neonatal comorbidities, surgical procedures and timing, respiratory and feeding support, length of stay and disposition are collected at key points during hospitalization as specified by CHND and subsequently validated or expanded upon by individual chart review. Further details about CHND have been previously published (Murthy et al. 2014).

Study Population

The site for this single center retrospective cohort study was Children's Hospital Colorado, an 84 bed level IV regional NICU with a multi-state referral area, access to medical and surgical subspecialists and a maternal–fetal center. This unit cares for preterm infants, infants with surgical or complex medical needs, and has access to therapies including therapeutic hypothermia and extracorporeal membrane oxygenation (ECMO). Inclusion criteria included: (1) infants ≤ 32 weeks gestational age admitted over the 5-year study period (2010–2014); (2) maternal residence located outside the metro area, defined as the six surrounding counties neighboring the study site; (3) infants without major congenital anomalies who were admitted to the NICU for the first time; and (4) infants who survived to discharge or transfer. Given the availability of several high risk obstetric delivery hospitals and associated level II and III NICUs in the metro area, we considered the population of preterm infants with maternal residence in the metro area to have medical and surgical needs beyond typical management of premature birth and thus would not be candidates for BT to lower levels of care. Other exclusions included infants who died before discharge home or readmissions with the generation of a second database record for a secondary admission after their initial NICU hospitalization after birth.

Clinical Covariates

The primary outcome of this study was the prevalence of BT to a nursery or NICU closer to maternal residence among infants admitted to a single level IV NICU. To evaluate the referral patterns of infants from outside the metro area, distance between referring hospital and level IV NICU was calculated and stratified into 100 mile increments. The study's secondary outcomes included: (1) length of stay in the level IV NICU in days, beyond the defined point of clinical stability, (2) impact of NICU census on BT, and (3) relationship between timing of surgical intervention and BT. Clinical stability was defined as being on full volume enteral feedings by gavage and on LFNC (defined as ≤ 1 LPM) without

ongoing need for positive pressure ventilation or parental nutrition. Bronchopulmonary dysplasia status at 36 weeks corrected gestational age was not consistently available for each infant in this cohort, therefore a new variable of oxygen requirement at 36 weeks corrected gestational age was generated and obtained by independent electronic medical chart review. To investigate the impact of bed availability on BT, weekly NICU census data were collected. For infants who required surgical intervention, the timing of surgery relative to BT or reaching clinical stability was assessed. The rationale for investigating surgical timing was to answer the question of whether among infants who reached clinical stability and were not back-transported, if they had been sent closer to maternal residence, might they have required another transfer back to the level IV NICU for surgical management such as gastrostomy tube placement.

Statistical Analysis

Maternal and infant demographic and clinical characteristics among BT and non-BT infants were compared using two-sample *t* tests for continuous variables and Fishers exact test for categorical variables. Fishers exact test was utilized given that some cell sizes had counts less than five. All variables were assessed for normality. Non-normally distributed variables were compared between the groups using the Wilcoxon rank-sum test. Multivariable logistic regression was used to assess the independent association between BT and each maternal/infant clinical and demographic characteristic. Estimates were adjusted for the following demographic and clinical characteristics: maternal age, race, ethnicity, referring hospital distance and intraventricular hemorrhage (IVH) grade at 28 days. Length of stay beyond clinical stability in days was summarized with medians and interquartile ranges (IQR) and compared between groups using a Wilcoxon rank-sum test. The study was approved by the Colorado Multiple Institutional Review Board (COMIRB). Statistical analyses were performed with R version 3.1.1 software (Vienna, Austria).

Results

We identified 6752 infants through CHND admitted to single free-standing children's hospital level IV NICU during the study period of 2010–2014 (Fig. 1). Among all NICU admissions, 6090 were excluded based on gestational age of ≥ 33 weeks and an additional 343 were excluded due to maternal residence being within the metro area. Other exclusions were death prior to NICU discharge (n = 36) and infants who were deemed to be ineligible secondary to being readmitted after being discharged home (n = 60). The study's final cohort included 223 total infants, of whom

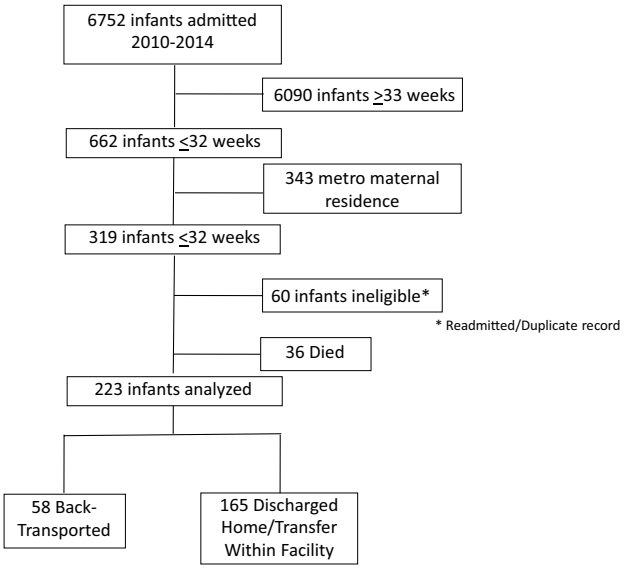

Fig. 1 Flow diagram of inclusion and exclusion criteria

26% (58/223) were back-transported to a unit closer to their maternal residence while 74% (165/223) were not back-transported and were either discharged home (n = 152) or transferred to the inpatient pediatric unit within the same hospital for chronic ventilation management (n = 13). Infants were admitted from nine states with a maximum referral distance of 822 miles from a referring hospital, as shown in the regional map (Fig. 2). Infants were referred from 39 unique hospitals within the region. Referral volume ranged from a single referral to as many as 41 referrals from one hospital throughout the study period.

Maternal and infant demographic and clinical characteristics of the cohort are summarized in Table 1. Maternal race, ethnicity, age, employment or parity did not differ significantly between the BT and not back-transported groups. A significant difference in insurance status was noted between the two groups; 62% of the back-transported infants had private insurance coverage compared to 35% of the not back-transported infants ($p < 0.01$). The back-transported infants overall were transferred further from the referring hospital; median transport distance of 559 miles (range 0.03–822 miles) for back-transported infants compared to 72.5 miles (range 0–822 miles) for not back-transported infants ($p < 0.01$). Note the referring hospital distances include infants inborn at the regional level IV NICU and infants transferred within the metro area but whose maternal residence was located outside the metro area.

In the bivariate analysis (Table 1), infant birth characteristics demonstrate younger (27.1 vs. 28.6 weeks' gestation) and smaller (928 g, [730, 1230 g] vs. 1224 g [855, 1618 g]) neonates in the back-transported group compared to the not back-transported group ($p < 0.01$). APGAR scores, incidence

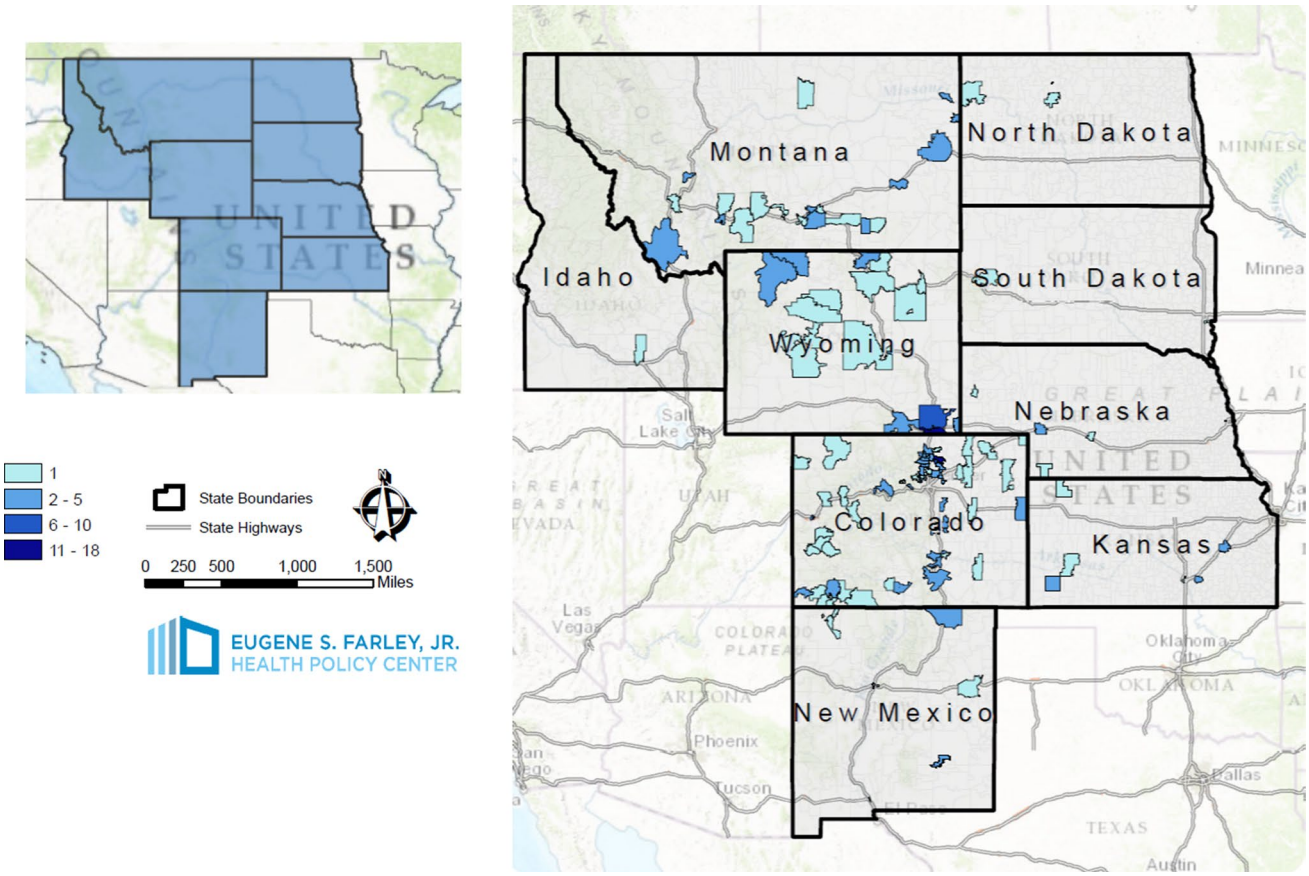

Fig. 2 Number of referrals to level IV NICU by maternal residence zip code

of necrotizing enterocolitis (NEC) or presence of seizures did not differ between groups. Infants in the back-transported group more often experienced severe IVH ($p = 0.02$) and higher oxygen requirement at 36 weeks corrected gestational age ($p < 0.01$).

No significant difference in the number of infants who underwent surgical intervention between the BT and non-BT groups was noted; the timing of surgical interventions differed with BT infants more likely to have surgical intervention prior to meeting criteria for clinical stability and non-BT infants more likely to have surgery after reaching clinical stability (71% vs. 67%, $p < 0.01$). The most common surgical procedures for the entire cohort are outlined in Table 2.

No significant association between BT and NICU census was noted, as demonstrated by the lack of difference in the overall weekly NICU census at time of clinical stability for infants who were back-transported compared to infants who were not back-transported (290 vs. 298, respectively, $p = 0.52$). Among the back-transported infants, no significant difference in the average weekly census at the point the infant reached clinical stability compared to the time when the infant was actually back-transported closer to maternal residence was found ($p = 0.88$).

In the multivariable analysis, referring hospital distance per 100 miles (adjusted odds ratio [AOR] 1.5; 95% CI 1.2, 1.8) and severity of IVH (AOR 2.8; 95% CI 1.2, 6.7) were significantly associated with BT. In addition, compared to privately insured infants, those infants with public insurance were significantly less likely to be back transported (AOR 0.3; 95% CI 0.1, 0.8). No significant association between BT with maternal race, ethnicity or maternal age was noted (Table 3).

The median length of stay in the regional level IV NICU for infants who were not back-transported was 28.5 days (IQR 5, 64 days) beyond meeting criteria for clinical stability, defined as the time of reaching respiratory stability on low-flow nasal cannula and nutritional stability on full volume enteral feedings.

Discussion

During the study period, we found that the majority of premature infants ≤ 32 weeks gestation admitted to the institution from outside the greater metro area were not back-transported closer to their maternal residence prior to

Table 1 Maternal and infant demographic and clinical characteristics

Variable	Back-transported (n = 58)	Home/transfer within facility (n = 165)	P value
Maternal race[a]			0.51
White	38 (86%)	117 (80%)	
Other	6 (14%)	29 (20%)	
Maternal ethnicity[a]			0.28
Hispanic/Latino	11 (22%)	48 (31%)	
Not Hispanic/Latino	38 (78%)	106 (69%)	
Maternal employment[a]			0.69
Full time	15 (44%)	47 (39%)	
Unemployed	19 (56%)	72 (61%)	
Paternal involvement[a]			0.74
No	4 (7%)	9 (6%)	
Yes	52 (93%)	152 (94%)	
Insurance status[a]			< 0.01
Private	36 (62%)	57 (35%)	
Public	22 (38%)	107 (65%)	
Antenatal steroids[a]			0.37
No	6 (13%)	24 (20%)	
Yes	39 (87%)	96 (80%)	
Maternal parity[a]			1
> 1	33 (59%)	96 (58%)	
1	23 (41%)	69 (42%)	
Maternal age[b]	28.1 ± 6	26.7 ± 6	0.12
Maternal parity[†]	2 (1,3)	2 (1,3)	0.87
Referring hospital distance (miles)[‡]	559 (0.03, 822)	72.5 (0, 822)	< 0.01
Gestational age[b]	27.1 ± 3	28.6 ± 3	< 0.01
Birth weight[†]	928 (730, 1230)	1224 (855, 1618)	< 0.01
Length of stay[†]	18 (10, 32)	59 (42, 87)	< 0.01
1 min APGAR[b]	4.9 ± 2	5.1 ± 2	0.50
5 min APGAR[b]	6.7 ± 2	6.9 ± 2	0.51
Oxygen at 36 weeks[a]			< 0.01
HFNC/CPAP	14 (35%)	25 (15%)	
LFNC	13 (32%)	60 (36%)	
MV	8 (20%)	17 (10%)	
RA	5 (12%)	63 (38%)	
IVH at 28 days[a]			0.02
No (grade 0)	26 (49%)	113 (71%)	
Yes			
Grade 1	9 (17%)	22 (14%)	
Grade 2	6 (11%)	8 (5%)	
Grade 3	5 (9%)	9 (6%)	
Grade 4	7 (13%)	7 (4%)	
ROP surgery[a]			0.33
No	48 (89%)	148 (94%)	
Yes	6 (11%)	10 (6%)	
Other surgery[a]			0.22
No	26 (46%)	91 (56%)	
Yes	31 (54%)	71 (44%)	
Presence of NEC[a]			1
No	51 (89%)	146 (88%)	
Yes	6 (11%)	19 (12%)	

Table 1 (continued)

Variable	Back-transported (n = 58)	Home/transfer within facility (n = 165)	P value
Presence of seizures[a]			0.65
No	55 (96%)	159 (98%)	
Yes	2 (4%)	4 (2%)	
Days of mechanical ventilation[b]	7 (4, 26)	6 (2, 8)	0.12

[†]Median and IQR, p-value from Wilcoxon rank sum test

[‡]Median and range, p-value from Wilcoxon rank sum test

[a]Categorical variables are presented with no. (%)

[b]Plus–minus values are means ± SD

Table 2 Most common surgical procedures

Surgical procedure	Number of cases
PDA ligation	36
Gastrostomy tube	28
Exploratory laparotomy	14
Tracheostomy	13
Subgaleal/VP shunt	6

Table 3 Multivariable analysis

Variable	AOR (95% CI)	P value
Referring hospital distance (per 100 miles)	1.5 (1.2, 1.8)	< 0.01
IVH Grade (per 1 grade increase in severity)	2.8 (1.2, 6.7)	0.02
Insurance status (public vs. private)	0.3 (0.1, 0.8)	0.02
Maternal race (White vs. non-White)	0.8 (0.3, 2.5)	0.64
Maternal ethnicity (not Hispanic/Latino vs. Hispanic/Latino)	1 (0.3, 3.1)	0.95

Adjusted for maternal race, maternal ethnicity, referring hospital distance, maternal age and IVH grade at 28 days

discharge home, after the point of reaching clinical stability. The prevalence of BT in this cohort was found to be 26%, confirming the hypothesis that less than half of eligible infants will have been back-transported closer to maternal residence. Significant predictors of BT included insurance status, gestational age, and distance from referring hospital. Average BT rates amongst preterm infants in other regions have not been published, making it unclear if the prevalence of BT in this cohort approximate other populations. The ideal prevalence of BT among the preterm population, while currently unknown, would aim to strike balance between access to acute care when needed, and when appropriate, provide opportunity for increased parental engagement with BT.

While availability of literature evaluating the association of neonatal BT and insurance status is lacking, the association between insurance status and neonatal transfer for a higher level of acute care has been described (Kunz et al. 2017). In one study, infants who are publically insured were more likely to be transferred than infants with private insurance (Durbin et al. 1997). Infants transported for acute care were more likely to be premature and have higher illness severity, although insurance status remained an independent predictor of transport when adjustment was made for both prematurity and illness severity. These findings contrast with our cohort of back-transported infants who were more likely to be privately insured. We hypothesize that this is related primarily to insurance coverage of elective and non-urgent transport costs which are more likely to be covered by private insurers. In addition, potential unmeasured confounders related to insurance status may also be present including parental request for transfer or other sociodemographic factors such as parental employment status.

Previous literature has demonstrated the association of gestational age and BT and is in alignment with our findings that infants of lower gestational age are more likely to be back-transported than infants born closer to term (Attar et al. 2005). These back-transported infants, compared to those infants who remain hospitalized in the regional NICU, are likely to have an overall longer length of stay prior to discharge home resulting in increased hospitalization duration for BT to be cost-effective (Phibbs and Mortensen 1992). With the lack of published literature on the relationship of BT and distance from referring hospital, we hypothesize that infants who are transported further from home are more likely to be BT when maternal residence is located in or near a larger metropolitan area with increased availability of hospital resources compared to rural areas with relatively fewer resources and neonatal capabilities.

The key finding of ongoing hospitalization at a level IV regional NICU in the non-BT group for an average of 28.5 days after attainment of clinical stability represents a significant time period of opportunity for infants to be back-transported closer to their maternal residence during the convalescing period of hospitalization. Potential practice implications for increased rates of BT include

improved parental engagement during hospitalization, increased parental comfort and competency regarding transition to home and home care practices such as feeding and safe sleep practices, and involvement of the outpatient pediatrician prior to NICU discharge.

Growing evidence supports family integrated care (FIC), a form of parental engagement during hospitalization that has been formally studied. FIC relies on consistent and frequent parental involvement and has been associated with improvement in short-term outcomes for preterm infants including decreased length of stay, improved weight gain and exclusive breastfeeding rates along with decreased parental stress and anxiety at discharge (Bastani et al. 2015; O'Brien et al. 2018; Ortenstrand et al. 2010). These benefits would likely be best achieved when preterm infants are hospitalized close to maternal residence and highlights the importance of considering BT for medically stable infants who are most likely to benefit from increased parental involvement. As previously demonstrated, potential for significant resource savings in a regional NICU for high-acuity beds, nursing and ancillary staff also exists (Zarif et al. 1979).

The potential risks and adverse consequences of BT must also be considered including increased post-discharge readmission rates. While re-admission rates for BT and non-BT infants did not vary in one prior study (Attar et al. 2005), additional research of larger contemporary NICU cohorts are needed to better address this question. While previous literature supports the overall safety of BT for clinically stable infants, well known risks associated with neonatal transport itself exist including hypothermia and clinical deterioration (Goldsmit et al. 2012; Skiold et al. 2015). Although many of these risks are most applicable to acutely ill neonates requiring emergent transfer to a higher level of care, these risks should be carefully considered when evaluating an infant's appropriateness for BT.

Our study did not demonstrate a significant association between average weekly NICU census and BT. In contrast, others have assessed the impact of NICU census on discharge to home of moderately premature infants (30–34 weeks gestation) found that the likelihood of discharge was greater when the NICU census was higher (Profit et al. 2007). The difference in results may potentially be attributed to a different decision-making process for back-transporting an infant versus discharging an infant home. Despite consistent availability of our specialized neonatal transport team for BT, a number of unknowns related to BT exist including the capabilities of the receiving nursery and the comfort of the receiving providers to care for a previously ill preterm infant, who despite achieving overall stability in the convalescent phase, remain at risk for complications. Units eligible to receive back-transported infants in our region are variably staffed with both neonatologists and pediatricians who may have different comfort levels in caring for these medically fragile patients.

Overall, our study findings have potential important policy and practice implications, especially for the western region of the United States which is overall less regulated with respect to perinatal regionalization of care and with fewer high level obstetric and neonatal care resources (Brantley et al. 2017). First, potential system level changes at the NICU or hospital level may include implementation of unit protocols that clearly define which infants are eligible for BT to level I or level II units closer to maternal residence. Thus, the decision to BT is not dependent on individual providers, but included as part of the NICU's FIC efforts to improve parental engagement in infant care prior to discharge home. Second, NICU providers, parents, and public health representatives may need to better understand (and potentially work to change) the insurance coverage of BT and its variation between public and private insurance providers so that parental involvement in their infants' care can be optimized.

Limitations

Limitations to this study include being single center. Our results may not be applicable to other regional NICUs based on local practice, state regulations and insurance coverage surrounding the process of back-transport. Access to longitudinal data for BT infants is not available within CHND to evaluate the total length of hospital stay for back-transported infants including their time in another NICU. Thus, we were not able to determine if BT is associated with a difference in overall length of hospitalization. Additionally, hospital charge data was unavailable and thus the evaluation of BT cost-effectiveness is not possible with these data. Other longer term outcomes including readmission rates and ED utilization post-discharge were not evaluated in this study. Factors that may impact BT including parental preference, insurance coverage of transport, subsequent ongoing hospitalization, and capabilities of level I or II units closer to the maternal residence are not available in these data sources.

Strengths

Strengths of this study include the use of the CHND, a robust clinical data system, to establish the cohort and analyze many of the clinical and demographic variables. This data was subsequently augmented with individual chart review via the electronic medical record. This is the first study, to our knowledge, which assesses the BT of preterm infants from a level IV unit and contributes to the overall sparse body of BT literature within neonatology. In addition, this study analyzes a geographically diverse population admitted from a wide catchment area with few other level IV

units in the region, indicating that the cohort captures many of the premature infants in the multi-state region who require higher levels of neonatal care.

Conclusions

The regional practice of BT of premature infants in this cohort demonstrates that many infants remain hospitalized in a level IV NICU for the duration of their neonatal hospitalization, despite having a significant opportunity for BT after reaching a point of clinical stability. Future research to further evaluate BT on a national level may provide additional insights into key drivers for this practice and reveal regional practices and patterns which may differ throughout the country.

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Compliance with Ethical Standards

Conflict of interest The authors have no conflicts of interest to disclose.

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