Improved outcomes of transported neonates in Beijing: the impact of strategic changes in perinatal and regional neonatal transport network services

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Original article

Background: **Infants born outside perinatal centers may have compromised outcomes due to the transfer speed and efficiency to an appropriate tertiary center. This study aimed to evaluate the impact of regional coordinated changes in perinatal supports and retrieval services on the outcome of transported neonates in Beijing, China.**

Methods: **Information about transported newborns between phase 1 (July 1, 2004 to June 30, 2006) and phase 2 (July 1, 2007 to June 30, 2009) was collected. The strategic changes during phase 2 included standardized neonatal transport procedures, skilled attendants, a perinatal consulting service, and preferential admission of transported neonates to the intensive care unit of the tertiary care center. Data from phase 2 (after- strategic changes) were compared with those of phase 1 (the period of pre-strategic changes) after a 12-month washout period, especially regarding the reduction in mortality and selected morbidity.**

Results: **There was a large increase in the number of transported infants in phase 2 compared with phase 1 (2797 *vs.* 567 patients). The average monthly rate of increase of transported infants was 383.3% (from 24 infants per month to 116 infants per month). The mortality rate of transported neonates reduced significantly from phase 1 to phase 2 (5.11% *vs.* 2.82%; *P*=0.005), particularly for preterm infants (8.47% *vs.* 4.34%; *P*=0.006). In addition, transported neonates during phase 2 had significantly decreased morbidities.**

Conclusions: **Regional coordinated strategies optimizing the perinatal services and transport of outborn sick and preterm infants to tertiary care centers improved survival outcomes considerably. These findings have vital implications for health outcomes and resource planning.**

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Key words: **morbidity; mortality; neonatal transport network; outcome**

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Introduction

Regionalization of high-risk perinatal care has been advocated for several decades in many countries. Intensive care for extremely ill and preterm neonates may lower the mortality and morbidity of infants. Evidence has also suggested that there are improved perinatal outcomes of infants following maternal transport before delivery compared to infants transported after birth.[1-3] However, preterm delivery, perinatal illness and congenital malformations cannot always be anticipated, resulting in a continuing need for the ex-utero transfer of neonates after delivery.[4-6] In China, high-risk infants born in rural areas are often transported to tertiary care centers for further treatment; however, regional neonatal transport systems are currently in the developing stage. Community hospitals often deliver high-risk pregnancies and preterm infants, and either the destination hospital or the non-tertiary hospital performs the majority of inter-hospital transfers of sick newborns. Nevertheless, some hospitals still depend on the adult transport system for transferring newborns. The neonatal mortality rate of high risk infants varies by the level of perinatal care and postnatal retrieval services.[7] In China, the reported incidence of hypothermia is 50%, the mortality rate is 24.2%, and the incidence of severe neurological sequelae is 24.5% among transported newborns.[8,9]

The shortage of intensive care facilities and neonatal intensive care beds necessitates the transfer of neonates between hospitals at the regional level, within the capital region of China. Since 2004, strategies for a composite Perinatal and Regional Neonatal Transport Network (PRNTN) have been developed with teams at Bayi Children's Hospital (Beijing, China). This network aims to reduce the incidence of mortality and morbidity associated with high-risk deliveries. PRNTN is an ambulance-based service with provisions for the transport of high risk neonates.[8] Several major changes were introduced to optimize the PRNTN service in July 2006. This study was designed to monitor the impact of these changes on the outcome of transported infants in Beijing, a region where short-distance neonatal transport was required and maternal transport was not well established during the study period. The study period was divided into two phases: July 2004 to June 2006, before the implementation of the major changes in the PRNTN (phase 1); and July 2007 to June 2009, after the implementation of the changes to the PRNTN (phase 2). There was a 12-month washout period, which established the intervention and minimized contamination. We hypothesized that the implementation of the changes in the PRNTN for transported newborns could significantly improve the outcome of outborn, high-risk infants.

Methods

Data collection

This study was approved by the Committee for the Protection of Human Subjects-Health Sciences of the General Hospital of Beijing Military Command and was funded by the Capital Medical Development Funding committee. The committee had no involvement in the study design, the collection, analysis, and interpretation of data, the writing of the report, and the decision to submit the paper for publication.

All transported neonates admitted to the Bayi Children's Hospital Nursery between July 1, 2004 and June 30, 2006 (phase 1) or between July 1, 2007, and June 30, 2009 (phase 2) were included in the study. Transported neonates included neonates from 93 community hospitals within a distance of 200 kilometers.

The PRNTN was established in 2004, and several major changes were introduced to optimize the system in 2006. First, the PRNTN received financial support from the Capital Medical Development Funding Committee, enabling the establishment of a tertiary care center with 120 beds for newborns at the Bayi Children's Hospital, which included 90 more beds than those in phase 1. Also, equipments for intensive care were updated, including mechanical ventilators, DuoPAP, incubators, and cardiorespiratory monitors. Second, the transport of neonates was accompanied by dedicated neonatal transport teams, as well as better transport facilities. The transport team that received the high risk neonates was dispatched within 10 minutes. Additionally, a perinatal consulting service (PCS), which is a statewide, fetal/neonatal/maternal specialist, telephone service and training program that provides assistance to community hospital doctors and obstetricians, was established. It aimed to encourage, coordinate and optimize the clinical conditions of neonatal transfers. The PCS was activated whenever there were uncertainties regarding the management of high-risk neonates and pregnancies.

The transport equipment included a portable incubator, a mechanical ventilator, infusion pumps, a cardiorespiratory monitor, a pulse oximeter, a suction apparatus, a glucose analyzer, a laryngoscope and endotracheal tube of necessary sizes, a neonatal nursing pack, and all the medications for neonatal resuscitation. Neonate transports were accomplished by dedicated neonatal transport teams from the Bayi Children's Hospital in the Dongcheng district. The transport team included fellows from the neonatology section and neonatal intensive care unit (NICU) staff nurses. Special training was provided to the transport teams with regard to the care of sick infants. The teams could contact the attending neonatologists at any time during transport, and the transported infants were admitted directly to the NICU bypassing the emergency ward.

Transport indications and diagnostic criteria for neonatal morbidities mentioned in the *Nelson's Textbook of Pediatrics* (17th Edition, Philadelphia) were used for the study purpose.[10] The established transport indications were as follows: (1) preterm infants [gestational age (GA) ≤34 weeks] or infants small for GA (<10th percentile) and birth weight ≤2000 g; (2) birth asphyxia; (3) in need of respiratory support; (4) cardiac disease; (5) surgical diseases; (6) congenital anomalies; (7) sepsis; (8) severe maternal complications, such as placental abruption, eclampsia, and premature rupture of membranes; and (9) others, such as hypoglycemia and jaundice. During transport, the peak inspiratory pressure was set to the minimal visible chest excursion and the oxygen concentration was fixed to keep the oximeter reading above 90%. The dopamine line was set before transportation if hypotension was anticipated. An infant was ready for transport after basic neonatal needs were met, which included a patent airway, adequate ventilation, a heart rate of 120-160 beats/min, oximeter >90%, a body temperature of 36.5°C-37°C and a corrected metabolic status.

All data were collected prospectively using uniform medical records and collated within the PRNTN by a designated data manager with a professional background in neonatal care. Transported neonates were defined as infants who were not born in the Bayi Children's Hospital. Infants who died before retrieval were not included for analysis. A preterm infant was defined as an infant born before 37 weeks of gestation.

Table 1. Characteristics of transported and inborn infants admitted before (phase 1) and after (phase 2) implementation of the retrieval and perinatal strategy

Variables	Transported neonates			Inborn neonates		
	Phase 1 (*n*=567)	Phase 2 (*n*=2797)	*P*	Phase 1 (*n*=114)	Phase 2 (*n*=262)	*P*
Gestational age at birth (wk)	36.2±4.1	35.9±4.4	0.135	36.0±4.2	35.4±5.1	0.271
Maternal age (y)	28.8±5.3	29.1±6.1	0.275	28.5±5.5	29.3±6.6	0.258
Birth weight (kg)	2.19±1.51	2.08±1.77	0.167	2.28±1.86	2.03±1.89	0.237
Male gender, *n* (%)	320 (56.4)	1558 (55.7)	0.748	61 (53.5)	145 (55.3)	0.742
Prenatal steroid, *n* (%)	418 (73.7)	2163 (77.3)	0.012	88 (77.2)	212 (80.9)	0.409
Age at NICU admission (d)	1.14±0.53	1.09±0.42	0.014			

NICU: neonatal intensive care unit.

A term infant was defined as infants whose gestational age was between 37 and 42 weeks. The primary outcome measure analyzed was neonatal mortality. The secondary outcome measures included the need for intubation, respiratory distress syndrome (RDS), chronic lung disease (CLD), retinopathy of prematurity (ROP), intraventricular hemorrhage (IVH), and necrotizing enterocolitis (NEC). The diagnosis of these neonatal diseases was based upon standard criteria.[10,11] Neonates that survived at least 28 days were included in the analysis for CLD and ROP.

Statistical analysis

Data were analyzed using SPSS 16.0 (SPSS, Chicago, IL). The Chi-square test and Student's *t* test were used to test the difference of categorical and continuous variables between the two phases. In order to avoid the contamination by the overall downward trend in outcomes, such as the progress of the neonatal intensive care, the difference-in-differences analysis technique was used to differentiate the impact of the strategic changes on the outborn mortality rate and other outcome variables from the overall downward trend in neonatal mortality rates over time. A two tailed $P<0.05$ was considered statistically significant.

Results

Transported newborns and NICU admissions

The admission pattern of inborn and transported neonates during the two phases is shown in Table 1. There was a large increase in the number of transported infants in phase 2 compared with phase 1 (2797 *vs.* 567), and the average monthly admission rate increased by 383.3% (from 24 infants per month in phase 1 to 116 infants per month in phase 2). The NICU admission rate also increased during phase 2 (3059 *vs.* 681). The proportion of outborn admissions to the NICU increased significantly from 83.3% (567/681) to 91.4% (2797/ 3059).

Comparison of neonatal mortality rate between the two phases

The mortality rate of transported neonates was reduced significantly from phase 1 to phase 2 (5.11% *vs.* 2.82%; P=0.005). This difference was accounted mostly for a reduction in the mortality rate of preterm infants (from 8.47% to 4.34%; P=0.006) (Table 2). The mortality rate in inborn infants also reduced, but it was not statistically significant (from 5.08% to 3.68%; P=0.700). The overall mortality rate was also significantly reduced from 4.99% in phase 1 to 2.84% in phase 2 (P=0.004). The reduction of mortality rates in transported neonates coincided with the strategic changes of the PRNTN and the inclusion of PCS.

Table 2. Mortality rate of transported and inborn infants admitted before (phase 1) and after (phase 2) implementation of the Retrieval and Perinatal Strategy

Gestational age	No. of deaths among transported neonates (%)	No. of deaths among inborn neonates (%)	Total deaths (%)
Total			
Phase 1	29/567 (5.11)	5/114 (4.39)	34/681 (4.99)
Phase 2	79/2797 (2.82)	8/262 (3.05)	87/3059 (2.84)
P	0.005	0.545	0.004
Preterm infants			
Phase 1	21/248 (8.47)	3/59 (5.08)	24/307 (7.82)
Phase 2	61/1405 (4.34)	5/136 (3.68)	66/1541 (4.28)
P	0.006	0.700	0.009
Full term infants			
Phase 1	8/319 (2.51)	2/55 (3.64)	10/374 (2.67)
Phase 2	18/1392 (1.29)	3/126 (2.38)	21/1518 (1.38)
P	0.110	0.640	0.078

Comparisons of the outcomes of transported and inborn NICU infants

Table 3 compares the morbidity data between the infants admitted to the NICU in the two phases. The outcomes of transported infants improved in phase 2, although these infants had a significantly higher morbidity rate as compared with inborn infants, especially with regard to severe IVH (12.5% of transported infants *vs.* 5.3% of inborn infants in phase 1; P= 0.026; 11.9% *vs.* 6.5% in phase 2; P=0.009). The incidence of the low 5-min Apgar score (<7), IVH, ROP and NEC did not change between the two phases.

Difference-in-differences evaluation

The difference-in-differences analysis evaluated the impact of strategic changes (intervention) by comparing

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Table 3. Major neonatal morbidities among transported and inborn infants admitted before (phase 1) and after (phase 2) strategic changes of the PRNTN services

Variables	Transported neonates			Inborn neonates			Difference-in-differences Analyses	
	Phase 1 (*n*=567)	Phase 2 (*n*=2797)	*P*	Phase 1 (*n*=114)	Phase 2 (*n*=262)	*P*	Difference, mean±SE†	*P*
Apgar score <7 at 5 min, *n* (%)	34 (6.0)	133 (4.8)	0.215	7 (6.1)	11 (4.2)	0.418	-0.6±4.2	0.039
Required intubation, *n* (%)	89 (15.7)	318 (11.4)	0.006	11 (9.6)	23 (8.8)	0.787	3.6±3.1	<0.001
RDS, *n* (%)	54 (9.5)	198 (7.1)	0.044	9 (7.9)	17 (6.5)	0.621	-6.5±4.3	<0.001
CLD, *n* (%)*	9 (1.6)	19 (0.7)	0.010	2 (1.8)	7 (2.7)	0.726	-3.2±2.9	<0.001
IVH, *n* (%)	71 (12.5)	332 (11.9)	0.663	6 (5.3)	17 (6.5)	0.649	-10.1±5.3	<0.001
NEC, *n* (%)*	3 (0.5)	21 (0.8)	0.790	1 (0.9)	2 (0.8)	1.000	-9.3±5.5	<0.001
Proven systemic infection, *n* (%)	29 (5.1)	94 (3.4)	0.042	4 (3.5)	11 (4.2)	0.789	-7.4±4.0	<0.001
ROP in preterm infants, *n* (%)*	6 (1.1)	51 (1.8)	0.335	2 (1.8)	9 (3.4)	0.517	-0.8±3.3	0.260

RDS: respiratory distress syndrome; CLD: chronic lung disease; IVH: intraventricular hemorrhage; NEC: necrotizing enterocolitis; ROP: retinopathy of prematurity; SE: standard error. *: numbers and incidences were examined only in preterm infants before and after strategic changes; †: improvements are negative values, indicating reduction of adverse outcomes.

the outcomes of the transported group relative to the inborn group during the different time periods. The inborn neonatal mortality rate decreased by 1.34%, whereas the transported neonate mortality rate decreased by 2.29% (Table 2). This resulted in a difference-in-differences of 0.95% ($P<0.05$), which is equivalent to a relative reduction in the mortality rate of transported infants of 18.59%. Stratification of the difference-in-differences value according to the GA showed significant relative improvement of the survival rate for preterm infants (relative improvement of 32.23%; $P<0.01$). The difference-in-differences analyses also showed a significant reduction in most neonatal morbidity rates for transported infants during phase 2 (Table 3).

Discussion

This study investigated the efficacy of strategic changes in the PRNTN service in Beijing, China over a 5-year period. Previous studies[5,6,12] have suggested that a specialized neonatal transport service could improve the outcome of high risk neonates, but antenatal transport would be more beneficial. Beijing is one of the world's most densely populated cities, with a population of 16.3 million and a birth rate of 0.832% in 2007.[13] High-risk births inevitably occur in non-tertiary hospitals, despite committed attempts to transfer at-risk women to perinatal centers before delivery by obstetrician teams. Therefore, modifications to prenatal advice, as well as improvements to neonatal transport network services and intensive care facilities, could significantly improve the survival of transported neonates and minimize morbidity.

This study showed that the strategic changes of the PRNTN service in 2006 was associated with a significant reduction (from 8.47% to 4.34%) in the mortality rate of transported preterm neonates. Our findings are particularly important because the rate of premature births will most likely increase in the near future, as maternal age at conception and the use of assisted conception are increasing.[6,8] The outcome improvements of these neonates are likely to be influenced considerably by concomitant advances in neonatal intensive care. Interestingly, the reduction in mortality rates of transported neonates was extremely rapid and even evident during a 12-month washout period. The speed during which these changes occurred is likely due to the strategic implementation of the PRNTN service. The difference-in-differences analyses showed decreasing trends in morbidities, such as IVH, CLD and NEC, which would lead to a further reduction in adverse neurodevelopmental outcomes. The higher rate of ROP was likely related to the increased premature infant survival rate. The high incidence of IVH among transported infants compared with inborn infants still remains a concern. To decrease the incidence of IVH, further approaches, such as better care during transportation, antenatal maternal transport or optimizing NICU care, are crucial.[14,15]

Adequate pre-transfer stabilization, safety during transport, and ongoing intensive care in the NICU are essential to improve the outcome of transported neonates.[6,8,16] Our study suggests that a well-managed PRNTN service can effectively meet these three requirements and improve outcomes of transported infants. The formation of an active neonatal transport service, with multiple, rapid-response, transport teams, most likely played a major role. McNamara et al[17] showed that a skilled transport team at high-risk deliveries was essential to improve the quality of neonatal resuscitation. Tertiary NICU care is pivotal for ensuring the ongoing and high-quality intensive care of transported neonates to avoid further compromise. We also noted that prenatal steroid therapy was better practiced in phase 2 among the mothers of transported neonates. This practice was likely a surrogate marker for improved peripheral hospital access to expert advice through the PCS network.

Fully dedicated neonatal transport networks and retrieval services have been established for approximately 20 years. They have been shown to be effective in

Australia and North America.[18,19] The wide-scale implementation of effective intervention is recognized as a central strategy to improve neonatal survival in developing countries.[20,21] Whether our findings can compare directly with strategies from other countries is difficult to ascertain because Beijing has a much higher rate of very-low birth weight infants needing transport than Australia or the United States.[6,22] Despite this, the benefits of regionalizing perinatal services (PRNTN) for high risk infants have been previously demonstrated.[23,24] The strategies described in this article might have important implications for the design and implementation of future network and newborn care programs in China and other developing countries.

Unfortunately, there were certain limitations and gaps in our study. First, there was a large difference in the number of transported infants during the two phases. Better availability of transport services and the availability of more beds at the tertiary center during phase 2 most likely played a role in these differences. We also did not acquire detailed information on the quality of resuscitation or support at delivery, stabilization procedures before and during transport at community hospitals, time interval between infant birth and transport, and training programs in perinatal care. Second, the outcome improvements were likely influenced by concomitant advances in standards of neonatal intensive care. These factors and other unmeasured factors might have confounded our findings.

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