Cost of Morbidities in Very Low Birth Weight Infants

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Objective To determine the association between direct costs for the initial neonatal intensive care unit hospitalization and 4 potentially preventable morbidities in a retrospective cohort of very low birth weight (VLBW) infants (birth weight <1500 g).

Study design The sample included 425 VLBW infants born alive between July 2005 and June 2009 at Rush University Medical Center. Morbidities included brain injury, necrotizing enterocolitis, bronchopulmonary dysplasia, and late-onset sepsis. Clinical and economic data were retrieved from the institution's system-wide data and cost accounting system. A general linear regression model was fit to determine incremental direct costs associated with each morbidity.

Results After controlling for birth weight, gestational age, and sociodemographic characteristics, the presence of brain injury was associated with a $12 048 ($P$ = .005) increase in direct costs; necrotizing enterocolitis, with a $15 440 ($P$ = .005) increase; bronchopulmonary dysplasia, with a $31 565 ($P$ < .001) increase; and late-onset sepsis, with a $10 055 ($P$ < .001) increase. The absolute number of morbidities was also associated with significantly higher costs.

Conclusion This study provides collective estimates of the direct costs incurred during neonatal intensive care unit hospitalization for these 4 morbidities in VLBW infants. The incremental costs associated with these morbidities are high, and these data can inform future studies evaluating interventions aimed at preventing or reducing these costly morbidities. *(J Pediatr 2013;162:243-9)*.

Very low birth weight (VLBW) infants (birth weight [BW] <1500 g) represent only 1.5% of all live births in the US,[1] but the cost of neonatal intensive care unit (NICU) hospitalizations for this group ranks them among the most expensive of all patients. These costs are roughly $13.4 billion annually, accounting for 30% of newborn health care costs in the US.[2-4] (Note: Throughout this article, costs are reported in 2009 US dollars using the 2009 Consumer Price Index.) The average NICU hospitalization for VLBW infants is 57.5 days.[2] NICU hospitalization costs are higher for surviving infants, given that most nonsurviving VLBW infants die during the first 2 weeks of life,[5-8] and both length of stay (LOS) and costs vary inversely with BW and gestational age (GA) in infants who survive NICU hospitalization.

These BW- and maturity-related health care costs are further increased by the fact that surviving VLBW infants are susceptible to numerous costly and potentially preventable morbidities that often require additional treatments, such as ventilation and surgery.[9-11] These morbidities not only increase NICU hospitalization costs, but also increase the risk of long-term chronic illness, rehospitalization, and developmental delay,[12-15] and thus have lifelong economic consequences for society at large.[16-21] Few studies to date have examined how these morbidity-related costs impact total costs borne by hospitals. Moreover, these studies performed only limited economic analyses, reporting only charges or adjusted charges using ratio of cost-to-charges instead of reporting actual costs borne by the hospitals.[2,10,11,19,20,22-25]

In the present study, we used microlevel cost data to more precisely determine the direct costs associated with the morbidities of brain injury (defined as intraventricular hemorrhage [IVH], periventricular leukomalacia [PVL], or acquired hydrocephalus[12]), necrotizing enterocolitis (NEC), bronchopulmonary dysplasia (BPD), and late-onset sepsis in surviving VLBW infants. Quantifying the direct costs will allow evaluation of the potential cost savings of therapies targeted at preventing these morbidities.

BPD	Bronchopulmonary dysplasia
BW	Birth weight
GA	Gestational age
ICD-9-CM	*International Classification of Diseases, 9th Revision, Clinical Modification*
IVH	Intraventricular hemorrhage
LOS	Length of stay
NEC	Necrotizing enterocolitis
NICU	Neonatal intensive care unit
PMA	Postmenstrual age
PVL	Periventricular leukomalacia
VLBW	Very low birth weight

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Methods

This retrospective study included all VLBW infants discharged alive between July 1, 2005, and June 30, 2009 from Rush University Medical Center with a principal or secondary *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) diagnosis code of 765.01-765.05 (extreme immaturity; <1500 g) or 765.11-765.15 (other premature infants; <1500 g). We excluded infants who died during the initial NICU hospital stay, given that most nonsurviving VLBW infants die during the first 2 weeks of life, before some of the morbidities evaluated here can be diagnosed.[5,6,8] We also excluded infants born at or transferred to another hospital, because of incomplete cost data. In addition, infants with missing race/ethnicity or ICD-9-CM diagnosis code for GA were excluded. This study was approved by Rush University's Institutional Review Board.

Clinical and economic data were retrieved from Rush University Medical Center's system-wide data and cost accounting systems. These data comprised detailed patient-level billing data, ICD-9-CM diagnosis codes, and clinical data extracted from the electronic medical record and associated data systems. The institution's cost accounting system reports the direct cost for each chargeable item (eg, room and board, personnel excluding physicians, drugs, medical and nonmedical supplies, equipment) used during each infant's hospital stay. The system also reports payments for the infant's hospital stay. A coexisting research database of these same surviving VLBW infants was used to determine the stage of NEC and treatment provided.

Neonatal Morbidities

Neonatal morbidities were identified using principal and secondary ICD-9-CM diagnosis codes documented by the attending neonatologist. Morbidities included brain injury (IVH [772.11-772.14], PVL [779.7], and acquired hydrocephalus [331.4]),[12] NEC stages 2 and 3 (777.5, 777.52, and 777.53),[26] BPD (770.7), and late onset sepsis, including culture-positive and culture-negative cases (771.81).

NEC was diagnosed when an infant demonstrated both clinical (abdominal distention, feeding intolerance, bloody stool, abdominal tenderness, or bilious residuals) and radiologic (pneumatosis intestinalis, portal venous gas, or pneumoperitoneum) features of NEC. Each case was reviewed and confirmed by one of the investigators (A.P.), including cases with a nonspecific NEC diagnosis code. Cases of spontaneous intestinal perforation were not included in the NEC cases. The primary analysis combined medically and surgically managed NEC, and then a secondary analysis examined these cases separately, because surgically managed cases represent infants with more severe NEC.[13]

BPD was coded by the attending neonatologist once the infant met the minimum criteria for mild BPD (ie, treatment with supplemental oxygen for 28 days but not at 36 weeks postmenstrual age [PMA]) based on the National Institute of Child and Human Development's classification scheme of mild, moderate (need for <30% oxygen at 36 weeks PMA), and severe BPD (need for ≥30% oxygen or positive pressure at 36 weeks PMA).[27] Further clinical data to subdivide these infants into severity groups were not available for this study. Late-onset sepsis was diagnosed when an infant aged >72 hours presented with clinical signs and symptoms (eg, apnea and bradycardia, increased respiratory distress, hypothermia, lethargy, pallor, feeding intolerance, hemodynamic instability) and laboratory test results (eg, leukocytosis with elevated immature cells, leukopenia, neutropenia, thrombocytopenia, elevated C-reactive protein) consistent with sepsis and received antibiotic treatment for a minimum of 5 days. Infants with negative blood cultures were classified as culture-negative sepsis if no other cause could be confirmed; for example, a confirmed case of NEC would not be diagnosed as sepsis with negative culture. Further clinical data to subdivide these infants into culture-positive and culture-negative groups were not available for this study. We used a dichotomous variable to indicate the presence or absence of each morbidity, as well as a variable to indicate the total number of unique morbidities (range, 0-4).

BW, GA, and Sociodemographic Characteristics

BW was classified into 4 categories: <750 g (ICD-9-CM diagnosis codes 764.x1, 764.x2, 765.x1, 765.x2), 750-999 g (764.x3 and 765.x3), 1000-1249 g (764.x4 and 765.x4), and 1250-1499 g (764.x5 and 765.x5). GA was also classified into 4 categories: <25 weeks (765.21-765.22), 25-26 weeks (765.23), 27-28 weeks (765.24), and 29-36 weeks (765.25-765.28). Sociodemographic characteristics included infant sex, infant race/ethnicity (non-Hispanic Caucasian, African-American/black, Hispanic Caucasian, or other), primary payer source (Medicaid or commercial payer), and total hospital LOS.

Direct Costs

For this study, hospital direct costs were the sum of the actual direct costs for each chargeable item (eg, electrolyte panel, room charges) incurred during the infant's hospital stay. Because physician fees were billed separately by the medical group rather than the hospital, physician fees were excluded from the hospital direct costs. Other ancillary staff costs, (eg, respiratory therapy, nursing, physical therapy, occupational therapy) were billed directly by the hospital and were included in the hospital direct costs.

Hospital direct costs were adjusted to year 2009 US dollars using the Bureau of Labor Statistics 2009 Consumer Price Index for urban consumers and all items.[4] Because costs for the Chicago metropolitan area are higher than the nationwide average, we deflated costs to reflect national average costs using the Centers for Medicare and Medicaid Services Occupational Mix Adjusted Wage Index for 2012.

Statistical Analyses

Frequencies and descriptive statistics were used to describe the sample. A generalized linear regression model was