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ORIGINAL ARTICLE

Cost, causes and rates of rehospitalization of preterm infants

MA Underwood[1], B Danielsen[2], WM Gilbert[3]

[1]Department of Pediatrics, University of California Davis School of Medicine, Davis, CA, USA; [2]Health and Information Solutions, Rocklin, CA, USA and [3]Women's Services, Sutter Health, Sacramento, CA, USA

Objective: To examine hospital readmissions for premature infants during the first year of life.

Study Design: The California maternal and newborn/infant hospital discharge records were examined for subsequent readmission during the first year of life for all newborns from 1992 to 2000. Discharge diagnoses, hospital days, demographic data and hospital charges for infants born preterm (<36 weeks gestation) were identified and evaluated.

Result: About 15% of preterm infants required at least one rehospitalization within the first year of life (average cost per readmission $8468, average annual cost in excess of $41 million). Infants with gestational age <25 weeks had the highest rate of readmission (31%) and longest average length of stay (12 hospital days). The largest cohort, infants born at 35 weeks gestation, had the highest total cost of readmission ($92.9 million). The most common cause of rehospitalization was acute respiratory disease. There was no decrease in the number or cost of readmissions of premature infants for respiratory syncytial virus infections following the introduction of palivizumab in 1998.

Conclusion: After initial discharge, premature infants continue to have significant in-patient health-care needs and costs.
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Keywords: resource utilization; low birth weight; length of stay; diagnosis-related groups; respiratory syncytial virus; palivizumab

Introduction

In spite of significant advances in obstetric, neonatal and pediatric care, premature infants remain a high-risk population following discharge from the Neonatal Intensive Care Unit (NICU).[1] Chronic lung disease, suboptimal nutritional status, relative immunodeficiency, anemia, developmental delays, increased socioeconomic stressors and exposure to common childhood pathogens are all factors in this high-risk equation. An estimate of the total cost of prematurity would include medical costs (initial hospital costs, rehospitalization costs, outpatient care by a variety of specialists, medications, supplies, equipment, home nursing care and so on), nonmedical costs (transportation, housing, special educational needs and so on), as well as opportunity costs (missed opportunities for work, education and the pursuit of happiness by parents, patients and other family members).[2] Several well-designed studies have looked at the cost of initial in-patient care of premature infants;[2–5] however, the costs and causes of rehospitalization of premature infants after initial discharge have not been well quantified.

Two recent studies demonstrated that the cost of care for premature infants after initial hospital discharge is higher than for term infants. One looked at the total medical cost in the first 2 years of life for 71 extremely low birth weight infants (birth weight <1000 g) born in Finland from 1996 to 1997.[6] These authors found that the total average cost for surviving extremely low birth weight infants was 105 000 euros (1996 US$134 000) with the initial hospital stay accounting for 64% and first post-discharge year in-patient costs accounting for 20% of this total. They also found that birth weight correlated negatively with initial NICU cost, but not with cost after initial discharge. The other study reviewed the cost and causes of hospitalization in the first 5 years of life for 240 000 infants of all gestational ages born in the United Kingdom between 1970 and 1993.[7] These authors found that average hospital readmissions within the first year of life for surviving preterm infants actually cost more than the average initial birth admission, and that hospital readmissions within the first year of life for the most premature infants (<28 weeks gestation) cost 30-fold more than those for term infants.

A questionnaire study of 547 infants born at <29 weeks gestation in France found that of the 376 infants for whom questionnaires were received, 47% were rehospitalized at least once in the first 9 months of life and 55% of those readmissions were for respiratory disorders. Rehospitalization was more common among infants with chronic lung disease, infants discharged between August and January and infants living with other children below the age of 6 years; the rate of these rehospitalizations did not correlate with gestational age.[1] A US study examined

Correspondence: Dr MA Underwood, Division of Neonatology, Surge 1, Room 1121, University of California, Davis, CA 95616, USA.
E-mail: munderwood@ucdavis.edu
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rehospitalizations of 1951 extremely low birth weight infants from the 14 centers of the National Institute of Child Health and Human Development Neonatal Research Network; 49% of these infants were rehospitalized before 18 months corrected age with respiratory, surgery and infection listed as the top three causes.[8] Neither of these studies looked at the cost of these readmissions. In a recent review, Petrou[5] notes that 'relatively few studies have documented the economic costs of preterm birth or low birth weight following the infant's initial discharge from the neonatal unit.' In this study, we look at the rates, causes and cost of rehospitalization of premature infants born in California from 1992 to 2000.

Methods

After obtaining approval from the California Committee for the Protection of Human Subjects, University of California, Davis and California Office of Statewide Health Planning and Development (OSHPD), the linked data for premature infants born in the state of California for the 9 years from January 1 1992 to December 31 2000 were examined. This large database links the infant birth and death certificate data (birth date, birth weight, gestational age and survival) with discharge summary data (discharge diagnoses, procedures performed, lengths of stay and hospital charges). We looked at all hospitalizations, including interhospital transfers, following initial discharge to home for all infants surviving to initial discharge with gestational age at birth <36 weeks in the first year of life. This database does not include births and hospitalizations in military facilities or births in out-of-state hospitals, private homes or birthing centers not reporting to OSHPD (total of less than 2% of all deliveries). A probabilistic linkage algorithm was used to perform the match. The linkage algorithm used by OSHPD has been highly successful linking over 97% of all infant and maternal discharges and the birth certificate. Detailed linkage results can be reviewed at http://www.health-info-solutions.com/links.html.

The database provides hospital charges rather than actual costs. Some California hospitals do not release data regarding their charges (for example, the Kaiser Permanente system), therefore only hospitalizations for which charges were available were included in cost calculations. Cost was then estimated using accepted cost-to-charge ratios.[9] To determine average cost per readmission, the denominator included only those hospitalizations for which charges/cost were available. We eliminated 1365 infants (0.52% of the total) from our study database for whom the reported gestational age was unreasonable for the reported birth weight.[10] The data were then grouped by gestational age at birth in completed weeks and by birth weight in intervals of 250 g and categorized by principal discharge diagnosis with associated total cost, average cost, total in-hospital days and average lengths of stay. The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) was used to code principal diagnoses and procedures.

Results

Table 1 provides a summary of the numbers, causes and cost of all rehospitalizations within the first year of life for preterm infants. The most common causes for readmission to the hospital were

Table 1 Length of stay and cost by cause of readmission of premature infants in California, 1992–2000, $N = 263\,883$

Principal diagnosis	*No. of readmits*	*% of all preterms*	*% of readmits*	*No. of hospital days*	*Average hospital days per readmit*	*Total cost in $ millions (% available)*[a]	*Average cost per readmit in $*
All	51 738	20	100	247 504	4.8	376 (86)	8468
Acute respiratory	18 127	6.9	35	88 742	4.9	133 (86)	8467
Non-RSV	13 953	5.3	27	65 288	4.7	93.3 (86)	7772
RSV	4174	1.6	8.1	23 454	5.6	39.3 (88)	10 750
Infectious	8378	3.2	16	36 746	4.4	41.3 (87)	5674
Gastrointestinal	7754	2.9	15	25 408	3.3	27.9 (87)	4153
Chronic respiratory	5804	2.2	11	31 190	5.4	45.4 (86)	9049
Hematologic	4033	1.5	7.8	10 066	2.5	8.83 (87)	2531
Fluid/electrolyte abnormalities	2050	0.78	4.0	8146	4.0	8.87 (87)	4983
Congenital anomalies	1883	0.71	3.6	10 025	5.3	21.6 (83)	13 900
Cardiac	1231	0.47	2.4	10 415	8.5	35.6 (87)	33 300
Trauma/abuse	852	0.32	1.6	4738	5.6	8.34 (87)	11 250
Neurologic	746	0.28	1.4	3080	4.1	4.84 (84)	7707
Other	6821	2.6	13	38 641	5.7	64.8 (82)	11 580

Abbreviation: RSV, respiratory syncytial virus.
[a]The number in parentheses represents the percentage of total readmissions for which hospital charge data are available.

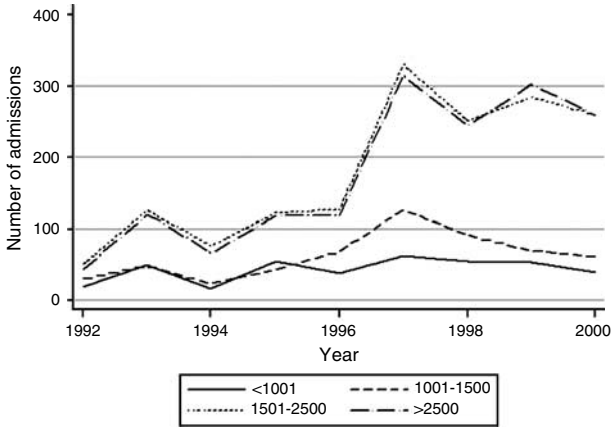

Figure 1 Readmissions of premature infants for RSV infection within the first year of life by year and birth weight.

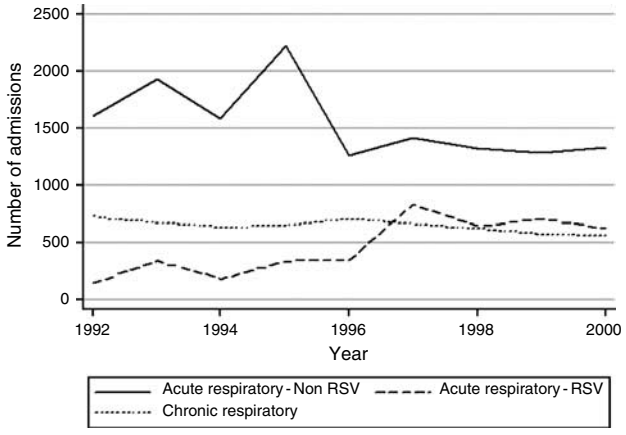

Figure 3 Readmissions of premature infants within the first year of life for respiratory diseases by year.

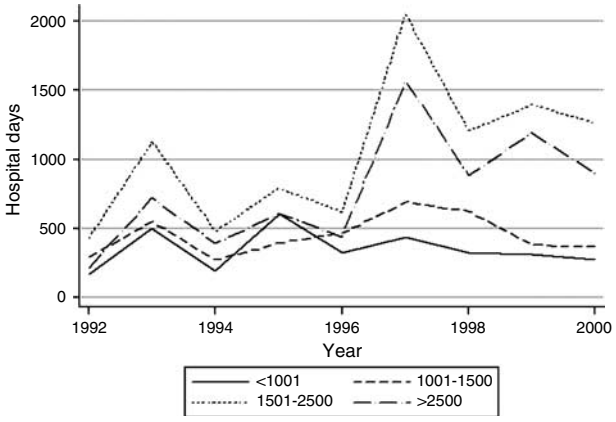

Figure 2 Total hospital days for premature infants with RSV infection within the first year of life by year and birth weight.

acute respiratory diseases, followed by nonrespiratory/non-gastrointestinal infectious diseases, gastrointestinal diseases and exacerbations of chronic respiratory diseases. The acute respiratory category includes a wide variety of upper and lower respiratory tract infections such as croup, bronchiolitis and pneumonia as well as infections caused by specific pathogens such as respiratory syncytial virus (RSV), *Streptococcus pneumonia*, and *Bordetella pertussis*. The chronic respiratory category includes diagnoses such as asthma, chronic respiratory insufficiency and chronic aspiration.

The numbers of readmissions and total hospital days for premature infants with a principal diagnosis of RSV infection by birth weight and year are summarized in Figures 1 and 2. Acute and chronic respiratory diseases including those with a discharge diagnosis of RSV infection for the 9-year period of this study are summarized in Figure 3. While palivizumab began to be given to premature infants in California in 1998, we do not detect a significant decrease in hospitalizations for RSV infection for the years 1998 to 2000 compared to the earlier years of the study.

Table 2 provides detail of number of infants readmitted, total hospital days, average length of stay and total cost for all readmissions subdivided by birth weight. The cohort with birth weight 501 to 750 g had the highest rate of rehospitalization. The cohort with birth weight >3000 g had the highest total cost and the highest number of hospital days. Table 3 provides similar details subdivided by gestational age at birth (in completed weeks). The small group of infants born at <25 weeks gestation account for 4.9% of the total cost of readmission, whereas the large group of infants born at 35 weeks gestation account for 25% of this total cost.

Discussion

Among the over 263 000 infants born during the study period with gestational age <36 weeks who survived (often after additional transfers) to a home discharge, 15% required at least one readmission to the hospital. This percentage is sharply lower than that of the previously noted studies. This is explained in part by differences in population and time period studied; however, comparisons of similar cohorts still demonstrate marked differences. For instance, in this study, considering the 16 512 infants with gestational age <29 weeks who survived to discharge, 27% required readmission to the hospital within the first year of life, compared to 47% readmitted in the first 9 months in the epidemiologic study of very preterm infant (EPIPAGE) cohort.[1] Considering the 11 509 infants in this study with birth weight <1001 g who survived to discharge, 29% required readmission within the first year compared to 49% within the first 18 months in the Neonatal Research Network study.[8] The reasons for these marked differences are not readily apparent. It is possible that the populations studied in the EPIPAGE and Neonatal Research Network studies represent a sicker population of infants such as

Table 2 Length of stay and cost of readmissions of premature infants by birth weight, California, 1992–2000

Birth weight (g)	N	*No. of infants readmitted*	*% of infants readmitted*	*No. of readmits*	*No. of hospital days*	*Average hospital days*	*Total cost in millions of $*
⩽500	346	97	28	158	1162	12	2.15
501–750	3770	1227	33	2148	15 710	13	26.9
751–1000	7393	1992	27	3175	18 641	9.4	30.6
1001–1250	9158	2135	23	3209	19 044	8.9	31.4
1251–1500	11 237	2151	19	3122	16 986	7.9	27.1
1501–1750	15 187	2512	17	3531	17 444	6.9	25.5
1751–2000	20 929	3149	15	4352	22 537	7.2	34.4
2001–2250	26 901	3834	14	5050	24 026	6.3	34.7
2251–2500	31 577	4498	14	5857	26 322	5.9	40.2
2501–2750	30 785	4253	14	5421	22 172	5.2	29.3
2751–3000	29 340	3807	13	4837	19 791	5.2	28.2
⩾3001	77 260	8800	11	10 878	43 669	5.0	59.4
Total	263 883	38 455	15	51 738	247 504	6.4	370

Table 3 Length of stay and cost of readmissions of premature infants by gestational age, California, 1992–2000

Gestational age (weeks)	N	*No. of infants readmitted*	*% of infants readmitted*	*No. of readmits*	*No. of hospital days*	*Average hospital days*	*Total cost in millions of $*
<25	2706	848	31	1417	10 090	12	18.2
25	2189	667	31	1088	7055	11	11.7
26	2910	796	27	1304	7497	9.4	11.5
27	3814	987	26	1530	9744	9.9	19.1
28	4893	1078	22	1632	9353	8.7	14.6
29	6324	1342	21	1976	10 972	8.2	15.6
30	9041	1670	19	2361	12 763	7.6	19.8
31	13 747	2251	16	3194	17 221	7.7	27.1
32	20 870	3033	15	4140	20 287	6.7	30.1
33	34 868	4745	14	6357	30 667	6.5	45.2
34	60 736	7936	13	10 137	44 378	5.6	64.3
35	101 785	13 102	13	16 602	67 477	5.2	92.9
Total	263 883	38 455	15	51 738	247 504	6.4	370

would be seen in referral center hospitals. It is also possible that the reported EPIPAGE data are influenced by sampling bias.

The largest portions of the total cost of prematurity are, of course, the initial NICU hospitalization after delivery followed by maternal costs. For the state of California, these costs for the year 2000 for infants weighing <2500 g were recently estimated, using methodology similar to that of this study, at $880 and $200 million, respectively.[3] In our study, the average annual cost for rehospitalization for the subset of infants weighing <2500 g was $28.1 million or roughly 3.2% of the total cost of the initial infant hospitalization. While differences in study design, cost accounting methods and health-care delivery systems make comparisons difficult, it appears that the cost of readmission in our study represents a smaller portion of the total in-patient cost of premature infants than those reported in the previously mentioned recent studies from Europe.[6,7] Similar to the study from the United Kingdom,[7] we found increased average cost per admission among infants <28 and <32 weeks compared to infants at 33 to 35 weeks.

In this study, percentage of infants readmitted, average length of stay and average cost of readmission all decreased with increasing birth weight and gestational age. Infants born at <1001 g represented 4.4% of all preterm births but accounted for 16% of the total cost of rehospitalization, suggesting that these smallest infants were the most vulnerable after discharge. Owing to their size, the very large cohorts of near-term infants had the highest total hospital days and total cost per cohort. Infants with birth weights >2500 g represented 52% of all preterm infants and accounted for 32% of the total cost of readmissions. The increased medical needs

of near-term infants have been an area of study in recent years. These infants as a group have higher in-patient costs per patient,[4] more medical problems[11] and higher rates of rehospitalization than term infants.[12] Our data suggest that near-term infants represent a significant portion of the cost of readmission for preterm infants. Some have proposed that delayed delivery in some of these near-term infants may be indicated.[9,13] A study currently in progress aims to shed light on the optimal management of near-term pregnancies.[14]

Respiratory syncytial virus is the leading cause of serious lower respiratory infections in children.[15] In our analysis, RSV infection was the single most common principal diagnosis leading to rehospitalization of premature infants. Palivizumab, a humanized monoclonal antibody, was shown in initial studies to decrease RSV hospitalizations in two groups of treated infants: those with bronchopulmonary dysplasia requiring medical treatment showed a 39% decrease, while premature infants (<35 weeks) age 6 months or less at enrollment showed a 78% decrease.[16] In 1998, palivizumab was approved by the Food and Drug Administration for prevention of serious lower respiratory tract disease caused by RSV and consideration of this medication was recommended by the American Academy of Pediatrics for premature infants.[17]

Subsequently, cost-effectiveness analyses of palivizumab in premature infants have been performed in a variety of settings. While these analyses have varied, all have questioned the cost-effectiveness of the initial American Academy of Pediatrics recommendations.[18–24] In many of these analyses, given its high cost, the infants for whom palivizumab was most likely to be cost-effective were those with gestational age <29 weeks gestation and/or those with chronic lung disease. While an analysis of the number of doses of palivizumab given from 1998 to 2000 is beyond the scope of this study, the current data suggest that a study of the impact of palivizumab on numbers of hospitalizations of premature infants for RSV infection is warranted.

This study has some limitations inherent to the methodology employed. First, the database underestimates by a small margin the total number of births and hospitalizations in California, as it does not include infants born in military facilities, birthing centers or private homes; nor would it be able to link preterm infants born out of state who then move to California and require hospitalization or infants born in California requiring hospitalization after leaving the state. Second, the implementation of ICD-9-CM coding is not standardized and there may be some variability in assignment of primary diagnosis. Two recent studies have however shown hospital discharge data to reflect accurately major diagnoses and procedures.[25,26] We attempted to overcome the possibility of this type of error by grouping diagnoses into broad categories. Third, this study is limited to rehospitalization during the first year of life. It is clear that the impact of premature birth extends much beyond this time period. Our intent was to look at a window of time when these small infants were perhaps most vulnerable. Finally, the process of converting hospital charges to costs is imperfect. Our method of conversion is standardized,[9] but gives at best an estimate of true costs. Furthermore, not all of the hospital systems in California report charges. Our reported cost represents the cost of the approximately 86% of readmissions for which hospital charge data are available. Thus, the totals reported are likely to be significant underestimates.

In summary, we have presented data regarding the rates, causes and cost of rehospitalization of premature infants in California. The smallest premature infants have the highest cost per readmission, but the large cohort of near-term infants has the highest cost per cohort. In spite of initiation of palivizumab in California, the cost of readmission for premature infants for RSV infections did not change within the time period studied.

Conflict of interest

The authors have indicated that they have no financial relationship relevant to this article to declare.

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