ABSTRACT. Background. Infants discharged from intensive care nurseries are a high-risk infant (HRI) population known to have increased utilization of medical services. Most studies tracking HRIs have been based on data obtained from individual chart review or direct patient contact. Given the high cost of such studies, it is desirable to develop less costly methods to track such infants.

Objectives. Our goals were: (1) to identify an HRI cohort at two neonatal intensive care units; (2) to identify a control group of infants not meeting HRI criteria; and (3) to measure outpatient and inpatient utilization in both cohorts using computerized files in a managed care organization.

Methods. Using California Children’s Services criteria as our starting point, we established an HRI definition. From a 1-year birth cohort of 7579 infants at two facilities, we identified 250 infants meeting the HRI definition at two neonatal intensive care units during 1990. We then matched the HRIs with a cohort of 896 randomly selected control newborns (those not meeting the HRI definition). Using organizational computer files and state of California death certificate tapes, we followed these infants until February 28, 1992. We measured the number of hospitalizations, total number of hospital days, and total number of outpatient visits and expressed these outcomes as rates per person-year. We also measured postdischarge mortality.

Results. The rate of hospitalization in the HRI group was 6.07 times (95% confidence interval [CI], 4.74–7.77) that in the control group. The utilization of hospital days by the HRI population (hospital days per 1000 person-months) was 13.24 times higher (95% CI, 11.00–16.04). The outpatient visit rate was 1.40 times higher (95% CI, 1.36–1.45) in the HRI population.

Conclusion. Our findings in a large managed care organization corroborate previous studies showing that hospitalization rates are significantly higher among HRIs. In our study population, outpatient utilization was significantly higher as well. Our study also demonstrates the feasibility of using computerized files to study outcomes in selected pediatric populations. These methods can be used for epidemiologic studies, interventional trials, and planning for resource allocation. Pediatrics 1996;97:693–699; neonatal intensive care, managed care, high-risk infant, very low birth weight, postdischarge utilization.

ABBREVIATIONS. NICU, neonatal intensive care unit; HRI, high-risk infant; KPMCP NCR, Kaiser Permanente Medical Care Program Northern California Region; CI, confidence interval; BW, birth weight; RR, relative risk; ICD-9CM, International Classification of Diseases, ninth revision Clinical Modification; VLBW, very low birth weight.

Survival of newborns has been increasing steadily. By the late 1970s, survival of infants between 1500 and 2499 g had increased to more than 95%; that of infants between 1000 and 1500 g had increased to more than 80%; and that of infants between 750 and 1000 g had increased to more than 50%. It is not clear whether decreases in mortality are being accompanied by decreases in other adverse outcomes (eg, cerebral palsy or the presence of handicapping conditions). In addition, several studies have shown that infants discharged from neonatal intensive care units (NICUs) use hospital resources more heavily than their well infant nursery peers.

It is reasonable to infer that infants discharged from NICUs would also use outpatient resources more heavily. Studies that reported a higher incidence of pulmonary complications among infants discharged from NICUs who required assisted ventilation, with and without chronic lung disease, suggest increased outpatient utilization. These studies report increased incidence of defined conditions such as developmental delay, chronic lung disease, and hearing problems. However, with the exception of a study by Lasky et al, studies in the literature do not report actual rates of utilization of outpatient resources by infants discharged from NICUs.

Given the higher rate of resource use by these infants and the increasing proportion of the population in managed care programs, it is urgent to begin addressing the outcomes of such infants outside of academic centers. Assessing utilization of medical resources is complicated by any factor leading to attrition from a study cohort, such as indigent status. For example, Lasky et al noted that, despite considerable efforts to prevent attrition, 43% of high-risk survivors from NICUs in an indigent population were unavailable for follow-up at the 1-year visit.

The current study was undertaken in a large managed care organization, the Kaiser Permanente Med-
ical Care Program Northern California Region (KPMCP NCR). This organization provides comprehensive care to all of its members. Health plan coverage includes medical services provided by subspecialists (eg, pediatric neurologists) as well as chronic hospitalization if necessary. Although certain services provided by the state of California (eg, ongoing physical therapy for a child with cerebral palsy) are not part of coverage plans, formal channels for referral to appropriate state agencies are in place at all medical centers.

The membership of the KPMCP NCR includes approximately 30% of the population in northern California. In 1990 and 1991, it was demographically similar to the general population in California, although the very poor and very wealthy were underrepresented. This region began to develop a health services research program in neonatology in 1991. Our study had three limited objectives. The first was to develop research methods suitable for a capitated system. The second was to use these methods to measure hospitalization and outpatient visit rates after discharge from the NICUs. Finally, we sought to assess the limitations of available information sources for future research projects in neonatology. Because of limited resources, we did not attempt to measure the intensity of resource use, other than length of stay, within a given hospitalization or outpatient visit. Because of many factors, among which is the relatively high socioeconomic status of our patient population, our loss to follow-up rate was only 10.3% among high-risk infants (HRIs) and 5.2% among control infants.

**METHODS**

**Definitions**

HRI. For the purposes of this study, the criteria for designation as an HRI were based on a modification of those used by California Children's Services. In California, children meeting these criteria are eligible for specialized diagnostic and therapeutic services. The California Children's Services high-risk criteria and those used in our study are substantially the same as those used in regional academic centers to screen for HRI follow-up and intervention. Therefore, they should identify and select a high-risk population comparable to those used in other such studies.

Infants were considered high risk if they survived to discharge from nurseries and met any of the following criteria: (1) birth weight (BW) less than 1500 g, (2) gestational age younger than 32 weeks, (3) the need for mechanical ventilation as a neonate, (4) abnormal results of an eye examination (retinopathy of prematurity or strabismus), (5) a major congenital anomaly (eg, coarctation of the aorta), (6) an Apgar score of less than 3 at 5 minutes, (7) the need for interhospital transport as neonate, (8) a cerebrospinal fluid or blood culture positive for pathogens as a neonate, (9) the need for total parenteral nutrition as a neonate, (10) a mother with a toxicology screen positive a drug of abuse, and (11) a stay in the NICU for more than 10 days. Criteria 7 through 11 were added by the investigators.

Control Infant. Infants were potential control infants if they did not meet any of the HRI criteria.

Outpatient Visits. These were defined as any visit to an outpatient department, including care at emergency departments and subspecialty clinics (eg, pediatric, neurology, cardiology, gastroenterology, and genetics) in the KPMCP NCR.

Same-day Hospitalization. This was defined as any admission to an inpatient setting not requiring an overnight stay. In our population, this was chiefly for elective surgery such as herniorrhaphy, circumcision, or strabismus repair.

**Case and Control Ascertainment**

The medical records of all NICU admissions during the 1990 calendar year at the two facilities were reviewed using a standard data abstraction protocol. In situations in which disagreements were possible, cases were reviewed by two of the investigators (S.C., G.J.E., and S.A.F.). For transported infants, the investigators were able to identify the exact dates on which the infants went home for the first time, which were used to define the start dates of the follow-up periods.

Using a random-number generator, control infants were selected from computerized records of all births at the two facilities during 1990 such that each birth had an equal probability of inclusion in the sample. Based on preliminary estimates of the SD of annual outpatient visits, we chose 945 control infants to compare with the 250 verified cases to achieve adequate power (80%) to detect a 1.5 visit difference in mean outpatient utilization between the two groups.

**Follow-up Period**

The follow-up period began on the date the infant first went home and ended on February 28, 1992. Thus, infants were followed for 14 to 26 months after discharge home.

**Mortality**

Organizational hospitalization computer files were scanned to identify all deaths that took place in the KPMCP NCR. For deaths outside of the hospital, patient demographic information was matched with all possible deaths on the state of California death certificate tapes using an automated mortality linkage system, which applies a combination of deterministic and probabilistic decision criteria to match records from a study population with the state mortality files.

**Postdischarge Utilization**

KPMCP NCR outpatient and inpatient automated registration and membership files (length of enrollment files) were scanned to ascertain the number of outpatient visits, same-day hospitalizations, overnight hospitalizations, total number of hospital days, and time periods when infants were not covered by the health plan. All hospitalization and visit records for KPMCP NCR utilization were collected by using the identifying medical record number for each patient. Given limited resources, no attempt was made to collect utilization data outside of Kaiser Permanente.

Current organizational databases that track out-of-plan use do not always permit disaggregation of out-of-plan use between different members of a given family.

**Statistical Methods**

Utilization rates were calculated as events per at-risk person-time for specific follow-up periods (eg, 7 to 13 months after discharge from the NICUs). This method allows for loss to follow-up time attributable to an infant leaving the health plan or death during the specified period.

Given that, in general, the distribution of utilization counts is skewed, nonnegative, and discrete, utilization rates were modeled using Poisson regression analyses. Unlike classical linear models, which assume a normally distributed dependent variable and a variance independent of the mean, the Poisson regression approach allows for the variance of the utilization counts to increase with the mean. The phenomenon of increased variability at higher mean levels of utilization is typical for such count data and is handled by this modeling approach by specifying that the variance of the outcome of interest is proportional to its mean.

Estimates of the ratio of utilization rates (HRIs versus control infants) and associated 95% confidence intervals (CIs) were obtained from these models. Adjustment was made for the time after discharge from the NICUs. In addition, we examined whether the association between risk group and utilization was constant over time by fitting the appropriate cross-product terms in the regression models (ie, group-time interactions).

**RESULTS**

**Study Population**

During the 1990 calendar year there were 7579 live births at the two study facilities. There were a total of...
291 births who met our HRI criteria. Of these, 12 died before discharge from the NICUs, and 29 were lost to follow-up, leaving 250 cases. Of the 945 randomly selected infants not meeting HRI criteria, 49 were lost to follow-up, leaving 896 control infants. The mean BW and gestational age of the 49 control infants and 29 HRIs lost to follow-up were not significantly different from those of the infants who remained in their respective cohorts. The final HRI cohort consisted of 62 infants with BWs of less than 1500 g, 79 infants with BWs of 1500 through 2499 g, and 109 infants with BWs of 2500 g or more. Table 1 provides more detail about the HRI cohort and those infants lost to follow-up. The Figure shows the results of our case and control ascertainment. At present, there are no Kaiser Permanente organizational data on changes in membership in the newborn population. Thus, it is not possible to ascertain to what extent our attrition rate could be explained by membership changes alone.

Postdischarge Mortality
No deaths occurred in the control infants; 10 of the HRIs died. Among those HRIs who died, the median time from first discharge home to death was approximately 1 month. Infants who died had a median gestational age of 35.5 (range, 25 to 40) weeks and a median BW of 2245 (range, 590 to 3875) g. Six of the deaths could be attributed to congenital heart disease, one to group B streptococcal meningitis, one to chronic lung disease, one to multiple congenital anomalies, and one to sudden infant death syndrome. The 10 infants who died did not have utilization patterns that were significantly different from those of the infants who survived.

Outpatient Utilization
Table 2 shows outpatient visit rates adjusted for time after discharge from the NICUs. Both the HRI and control populations were stratified by weight class. Given that control infants with BWs of 2500 g or more are the reference group, the associated risk ratio for this group is by definition equal to 1. Relative to this value, HRIs in all three weight classes (<1500, 1500 through 2499, and >2499 g) had increased outpatient utilization, with relative rates ranging from 1.31 to 1.51 times higher than those in the control group. This increase in outpatient utilization holds for all three time periods evaluated, (0 through 6, 7 through 12, and 13 or more months after discharge). Before 1994, KPMCP databases did not permit disaggregation between different visit types, so we could not distinguish between scheduled well infant examinations and unscheduled outpatient visits.

Hospitalization
The HRI group had more overnight hospitalizations. The adjusted rate of hospitalization was 6.07 times higher (95% CI, 5.20-7.11) in the HRI group. These infants also spent more days in the hospitals. Table 3 shows age-specific overnight hospital days per 1000 person-months adjusted for time since discharge from the NICUs. As with outpatient utilization, control infants with BWs of 2500 g or more serve as a reference group. Note that the small number of control infants in the less than 2499-g BW class leads to less precision and somewhat wider CIs. Relative to the control infants, all three weight

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**TABLE 1. High-risk Infants Admitted and Discharged From Study Facilities**

<table>
<thead>
<tr>
<th>Characteristics of Infants</th>
<th>Facility A</th>
<th>Facility B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live births, all BWs</td>
<td>3496</td>
<td>4083</td>
</tr>
<tr>
<td>Inborn NICU admits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 g BW</td>
<td>17</td>
<td>44</td>
</tr>
<tr>
<td>1500-2499 g BW</td>
<td>170</td>
<td>126</td>
</tr>
<tr>
<td>≥2500 g BW</td>
<td>388</td>
<td>286</td>
</tr>
<tr>
<td>Outborn NICU admits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 g BW</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>1500-2499 g BW</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>≥2500 g BW</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Total NICU admits meeting HRI</td>
<td>127</td>
<td>170</td>
</tr>
<tr>
<td>study definition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NICU deaths</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Total NICU admits meeting HRI</td>
<td>122†</td>
<td>162†</td>
</tr>
<tr>
<td>study definition and surviving to discharge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost to follow-up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 g BW</td>
<td>...</td>
<td>1</td>
</tr>
<tr>
<td>1500-2499 g BW</td>
<td>10†</td>
<td>6†</td>
</tr>
<tr>
<td>≥2500 g BW</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Remained in cohort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 g BW</td>
<td>25‡</td>
<td>39‡</td>
</tr>
<tr>
<td>1500-2499 g BW</td>
<td>41§</td>
<td>39§</td>
</tr>
<tr>
<td>≥2500 g BW</td>
<td>41</td>
<td>68</td>
</tr>
</tbody>
</table>

* BW indicates birth weight; NICU, neonatal intensive care unit; and HRI, high-risk infant.
† Five infants spent time at both NICUs, so the total number of potential cases is 279.
‡ Two of these infants spent time at both NICUs.
§ One of these infants spent time at both NICUs.
classes of HRI (<1500, 1500 through 2499, and >2499 g) had strikingly increased the number of hospital days. The relative risks (RRs) for the number of hospital days were highest in the second 6-month follow-up interval than in the early or later time periods. RRs of HRIs compared with control infants ranged from 13.77 to 30.8 for the second 6-month follow-up period and from 2.75 to 5.62 for the period after 12 months after discharge. Although a markedly increased rate of hospitalization in the HRI group applies to all three time periods evaluated (0 through 6, 7 through 13, and 13 or more months), hospital days drop off steeply in both control and HRI groups after 13 months. Similarly, utilization of overnight hospital days by the HRI group (hospital days per 1000 person-months) ranged from 8.0 to 22.2 times higher than in the control group. This increase was present regardless of BW.

HRIs also had higher rates of same-day hospitalization during all time periods. The overall RR for these hospitalizations was 5.26. Unlike overnight hospitalizations, which peaked in the 7- to 13-month postdischarge period, same-day hospitalizations were most frequent after 13 months.

The five most common principal diagnoses among hospitalized HRIs were bronchiolitis (International Classification of Diseases, ninth revision Clinical Modification [ICD-9CM] code 466.1), inguinal hernia (ICD-9CM code 550.9x), unspecified viral illnesses (ICD-9CM code 79.9), bronchitis (ICD-9CM code 466.0), and asthma (ICD-9CM code 493x). Among the control infants, the five most common diagnoses were jaundice (ICD-9CM code 774.6), bronchiolitis (ICD-9CM code 466.1), inguinal hernia (ICD-9CM code 550.9x), unspecified viral illnesses (ICD-9CM code 79.9), and unspecified pneumonia (ICD-9CM code 486).

A more detailed breakdown of rates of outpatient visits, same-day hospitalizations, and overnight hospitalizations is available from these investigators.
Verification of Accuracy of Electronic Data

We randomly selected a subset of 63 HRIs and 87 control infants. Their outpatient and inpatient records at all 29 KPMCP NCR facilities were reviewed to assess the accuracy of computerized data. The two sources were in agreement for the number of overnight hospitalizations and hospital days for all infants. In 146 of these 150 infants, the two data sources were in agreement on the number of same-day hospitalizations; the disagreement in the remaining 4 infants was only by a single event. The electronic sources for these 150 infants identified 95% of the outpatient visits found on chart review (3065 of 3226 visits). The median numbers of outpatient visits for these 150 infants identified 95% of the outpatient visits found on chart review (3065 of 3226 visits). The median numbers of outpatient visits in the remaining 4 infants was only by a single event. The electronic sources for these 150 infants identified 95% of the outpatient visits found on chart review (3065 of 3226 visits). The median numbers of outpatient visits for these 150 infants identified 95% of the outpatient visits found on chart review (3065 of 3226 visits). The median numbers of outpatient visits for these 150 infants identified 95% of the outpatient visits found on chart review (3065 of 3226 visits).

DISCUSSION

HRI Hospitalization After Discharge From the NICU

Our findings are consistent with previous reports. Hack et al reported that 33% of very low birth weight (VLBW; <1500 g) survivors were rehospitalized in the first year of life, 10% were rehospitalized in the second year, and 10% were rehospitalized in the third year. McCormick et al noted that as many as 40% of VLBW infants had almost two hospitalizations, with an average of 16 days in the hospital, as compared with 19% of all low BW infants, with an average of 12.5 days, and 8.7% of normal BW infants, with an average stay of 8 days. Hack et al also noted a threefold increase in medical conditions and surgical procedures during childhood among VLBW survivors. Ford et al reported a significantly increased rate of rehospitalization in a similar population. McCormick et al found that a population of high-risk infants whose BWs were 2500 g or less had a rate of rehospitalization of 19% by 1 year of age versus 8.4% for HRIs with BWs of more than 2500 g. In the same sample, the rate of rehospitalization by 1 year of age was 38% in infants weighing less than 1500 g. This increased risk of rehospitalization held true even among “advantaged” infants and those without evident chronic conditions or developmental delay. Mutch noted a fourfold increase in rehospitalization (34% vs 9%) during the first year of life in VLBW survivors and a twofold increase in the second year of life, attributing this mainly to an increased risk of respiratory illness and the need for surgical procedures, especially hernia repair. Again noting improved survival of VLBW infants since the 1940s, Mutch et al reported a twofold relative rate of rehospitalization among VLBW survivors in the 1940s versus a fourfold increase in the 1980s. Other studies have confirmed these findings.

Outpatient Utilization After Discharge From the NICU

Our data show increased use of outpatient resources by HRIs. The increased use is similar in magnitude to that reported by Lasky et al. Although data showing increased resource use by HRIs are not widely available from other sources, one can infer that such resource use is high. For example, using data from the National Health Interview Survey, Newacheck et al reported that the 3.8% of children determined to have chronic conditions accounted for 9% of the outpatient visits and 30% of the inpatient days. McCormick and Shapiro also noted that the number of physician visits was higher for low BW survivors than for those with normal BWs. They reported that VLBW infants had an average of 14 to 16 visits during their first year compared with 10 visits for normal BW infants.

As early as 1966, Abramowicz and Kass speculated on the likelihood of an increased risk of illness in general in low BW survivors. Budetti and Newacheck note a near doubling in the number of children with limiting conditions caused by chronic illness since 1960 and speculate that this phenomenon is in part attributable to increased survival of low BW infants. The cost of caring for these disabled children is high and can be anticipated to increase as more survive. Newacheck and McManus reported that in a sample of children with chronic disabilities, 10% of the sample were responsible for 60% of the total expenditures.

We noted an increase in overnight hospital days in both the control infants and HRIs in the interval between 7 and 12 months of age (Table 3). This is not unexpected given the natural decrease in maternal antibody titers expected by this age. Hospital days declined in the groups 13 or more months after discharge.

Methodological Aspects

Our study demonstrates the feasibility of computerized tracking of discrete pediatric subpopulations in a capitated system. Our entry criteria focused on infants discharged from NICUs, but there is no reason why these methods cannot be used for other at-risk populations, such as 2- to 4-month-old infants with respiratory syncytial virus infection.

Methods for doing this type of study in pediatrics often have relied on extensive chart reviews, direct patient contact, or household interviews, such as the National Health Interview Survey. Although it is clear that interview or direct patient contact studies will always be needed, the method used in this study suggests that computer files maintained by managed care organizations for operational purposes can find a use in pediatric research.

Limitations of This Study

One important limitation of our study is the discrepancy between computerized data and those obtained by chart review. There will always be some discrepancy between these methods. However, the relatively low discrepancy between these two sources of information is more than offset by the convenience of this method when one considers the logistic difficulties involved in conducting chart reviews in managed care organizations with multiple facilities (29 in the case of our study), let alone in...
setting up specialized tracking systems for designated follow-up clinics. Although the quality of the data in our study method is not suitable for all questions involving the outcome of infants discharged from NICUs (e.g., defining the long-term effects of a given mechanical ventilation protocol), it is certainly acceptable for some epidemiologic purposes, as well as for decisions regarding resource allocation within capitated systems.

Another important limitation imposed on the study by available resources was that we did not measure utilization outside of the KPMCP NCR. Because the KPMCP NCR is a very large region offering comprehensive care, the underestimate is most likely to involve very sophisticated and specialized services (e.g., extremely complex cardiac surgery). Thus, this issue would be expected to have a greater effect on measuring utilization among HRIs than among control infants (particularly when considering HRIs with congenital anomalies). Our inability to capture this information in this study clearly limits the generalizability of our findings. Because of this issue, we are analyzing databases that capture out-of-plan use and intend to restructure them to facilitate future pediatric research.

There is no question that HRIs discharged from nurseries will require more services than healthy infants. In an era of constrained resources, it is critical not only to define outcomes among such infants but also to examine to what degree resource consumption is actually associated with such outcomes. In addition to use for planning and resource allocation, such information can be used to define the need for interventions and, later, to measure the effect of such interventions. For example, our data show that despite higher outpatient services use in the HRI group, the increased number of outpatient visits is not associated with decreased hospitalizations. This suggests that outpatient treatment strategies for HRIs in managed care organizations need to be re-examined. It would be very informative to be able to compare our data with similar data from different hospitals and hospital groups.

CONCLUSIONS

The findings in this study are similar to those of others, namely, that the rate of hospitalization is significantly higher in an HRI population. The magnitude of this increased risk is similar to that previously reported. The present study also found that our HRI population has markedly higher use of hospital days and outpatient visits. It is significant that this increased resource consumption occurs even among a selected population with health insurance in a managed care organization.

Our study also found that computerized outcome studies in defined pediatric populations can yield results with acceptable data quality. An important implication of our study is that if common definitions were adopted across different institutions, it would be possible to conduct very large studies focusing on outpatient outcomes in discrete pediatric subpopulations.

ACKNOWLEDGMENTS

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AID$

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Condom makers, mail-order drug companies, home health care services, vitamin, and health food stores have all benefited from the AIDS epidemic.


Submitted by Student
Postdischarge Utilization of Medical Services by High-risk Infants: Experience in a Large Managed Care Organization
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