Explaining resource consumption among non-normal neonates

by Rachel M. Schwartz, Thomas Michelman, John Pezzullo, and Ciaran S. Phibbs

The adoption by Medicare in 1983 of prospective payment using diagnosis-related groups (DRGs) has stimulated research to develop case-mix grouping schemes that more accurately predict resource consumption by patients. In this article, the authors explore a new method designed to improve case-mix classification for newborns through the use of birth weight in combination with DRGs to adjust the unexplained case-mix severity. Although the findings are developmental in nature, they reveal that the model significantly improves our ability to explain resource use.

Introduction

A number of research efforts to date have focused on neonates because the Medicare program uses only seven diagnostic categories to describe both sick and normal infants. Researchers have identified that the neonatal diagnosis-related groups (DRGs) explain only 16 to 22 percent (Phibbs et al., 1986; Resnick et al., 1986) of the variation in costs and length of stay. These authors and others (Poland et al., 1985) have pointed out large differences in mean length of stay and charges in caring for high-risk patients compared with the published Medicare mean for the DRGs. Problems were most prominent in DRGs 385 (neonate, died or transferred), 386 (neonate, extreme immaturity or respiratory distress syndrome), and 387 (prematurity with major problems). These authors (Schwartz et al., 1989) examined this issue elsewhere and identified large differences in measures of length of stay and cost per case within the high-risk neonatal DRGs. Finally, cases that met the Medicare criteria for outlier payment were found to constitute a very high percentage of cases in these DRGs in teaching hospitals. (Berki and Scheier, 1987).

The implication of the findings noted is that each DRG, designed to be a homogeneous group of patients, is actually a heterogeneous group of patients. Furthermore, fixed case-level payment amounts based on DRGs that are not truly homogeneous result in inadequate payment for high-risk cases in hospital with case-mix distributions that include a disproportionate number of severely ill patients (Schwartz, 1989). The high degree of regionalization of care for high-risk newborns may exacerbate the problem.

The limitations of the neonatal DRGs are relatively unimportant for the Medicare program because very few neonates or children are entitled to program benefits. However, potential payment inequities may be very important outside the Medicare program. As of February 1991, there were 20 States that use DRG-based payment systems. A number of States (New York, Florida, and Michigan), in recognition of the problems, have revised the neonatal DRGs for their own use, and the proliferation of this relatively new method of payment is proceeding rapidly among States. In addition, the use of case-based payment systems has been mandated for both the Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) and the Indian Health Service. Both these programs provide a high volume of services for newborns; therefore, broad-based implementation of the Medicare DRGs as now defined could create financial disincentives for hospitals serving high-risk patients.

Changes in DRGs have been suggested by many (Phibbs et al., 1986; Resnick et al., 1986; Poland et al., 1985); in particular extensive work has been performed by the National Association of Children's Hospitals and Related Institutions (NACHRI) (Lichtig and Kannf, 1989). These last authors proposed the use of pediatric modified diagnosis-related groups (PMDRGs) for all children. This approach was recently modified and implemented in New York State and by CHAMPUS. Work completed concurrently with the analyses presented here was performed by the DRG refinement project at Yale University (Yale University Health System Management Group, 1989). Their work is similar to, although somewhat simpler than, the plan prepared by NACHRI.

The NACHRI work addresses the problem of DRG performance by creating 47 categories that use a combination of discharge status, birth weight, mechanical ventilation, and additional clinical parameters within the coding structure found in the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) (Public Health Service and Heath Care Financing Administration, 1980). One purpose of our analysis is to explore whether so many categories are needed to explain resource consumption. The heavy reliance of PMDRGs on birth-weight categories is justified by the powerful relationship between birth-weight categories and resource consumption (Schwartz, 1989). The importance of mechanical ventilation in predicting costs was also documented by NACHRI (Lichtig and Kannf, 1989) but can be abused along the lines described by Simborg (1981). In addition, the use of mechanical ventilation to adjust for severity of illness could become problematic because it is increasingly recognized that mechanical ventilation use is correlated with the quality of care. Specifically, there is a large variation across neonatal intensive care units in the incidence of bronchopulmonary dysplasia (an iatrogenic condition); much of this variation is attributed to differences in care (Avery et al., 1987).

In this article, we compare the DRG and PMDRG groupings and present an alternative that uses DRGs, with birth weight as a severity measure. In exploring a new approach, we hoped to improve the explanatory power of

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the DRG model without creating a large number of groups or using medical procedures to define groups. Our approach is to add a continuous birth-weight function to the current DRGs for sick newborns. This allows full exploitation of the strong correlation between birth weight and resource consumption by newborns. We use regression analysis to compare the predictive power of the models.

Data and methods

Data source and description

The data for this study were developed under a grant awarded to examine the impact of DRGs on perinatal care regionalization. A stratified random sample of 50 urban hospitals in 1985 were selected from the universe of urban hospitals with more than 900 births. The sample was designed to both compare the case mix in tertiary and non-tertiary hospitals and to make general observations about the case mix in urban hospitals in the United States. One year of case-level patient data from discharge abstracts was collected from each hospital.

The design grouped hospitals as tertiary or non-tertiary and then divided them into categories based on size (using number of acute care beds) and teaching intensity (using number of residents per bed). A tertiary hospital was defined as any hospital with a neonatal intensive care unit that serves as a regional resource. These hospitals were identified nationally by using both American Hospital Association (1984) survey data and a supplemental 1985 survey (by these authors) of State maternal and child health directors. Non-tertiary hospitals were those with more than 900 births but without a neonatal intensive care unit.

The sample design had 28 cells and required two hospitals from each cell; hence, 56 hospitals were to be selected. In the non-tertiary group, two cells were empty. The non-tertiary hospital group had two drop-outs, thus leaving a sample of 22 non-tertiary and 28 tertiary care facilities. These 50 hospitals had an average of 445 beds with 0.13 residents per bed, compared with the group of 1,045 hospitals with more than 900 births, which had an average of 410 beds with 0.10 residents per bed. The 50-hospital sample was statistically larger with greater teaching intensity, but the actual differences were small.

There were 134,118 infants in the hospitals studied. As shown in Table 1, using the sample weights, the 50-hospital patient sample represents 84 percent of the births in urban hospitals and 81 percent of newborns with birth weights less than 2,500 grams in the United States.

Each hospital provided the uniform hospital discharge data set plus birth weight and billing information for all neonates admitted during a 12-month period from November 1985 through July 1987. This data set provided the following information on each patient: up to 15 diagnoses using the ICD-9-CM codes; up to seven procedures; date of birth; sex; admission data; discharge date; discharge status; birth weight; payer; ZIP Code; room and board charges; radiology charges; surgery charges; laboratory charges; pharmacy charges; and intensive care charges. Each hospital also provided a copy of the Medicare Cost Report for the 12-month period corresponding to the data supplied.

Table 1

Means and cutoff points for patients within major diagnostic category 15, by diagnosis-related group (DRG)

DRG		Geometric mean length of stay[1]	Outlier cutoff
385	Neonate, died or transferred	3.7	22
386	Neonate, extreme immaturity	17.9	36
387	Prematurity with major problems	13.3	31
388	Prematurity without major problems	8.6	27
389	Full-term neonate with major problems	7.4	25
390	Neonates with other significant problems	4.2	20
391	Normal newborn	3.1	7

[1]*Federal Register* (1987).

NOTE: Major diagnostic category 15 includes newborns and other neonates with conditions originating in the perinatal period.

SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

The data sets were expanded in two ways prior to the analyses. First, the charges were converted to costs to allow a greater level of internal consistency in the data; second, the DRGs and PMDRGs were added (as explained in the next section).

To add cost data to the data set, a cost report analysis, following the approach used by Medicare, was performed. This approach allowed for the consistent transformation of all charge data to cost data for each case within each hospital; therefore, each case includes a variable "total cost." Finally, all cost data were adjusted to the calendar year 1985 using standard adjustment techniques.

Case-mix classification systems

Patients were classified using both DRGs (effective October 1, 1987) and PMDRGs (version 5.0). The DRGs group newborns into seven categories, with six groups for

Table 2

Sample hospital births compared with urban births and U.S. births: 1985

Item	Sample	Sample universe-represented	U.S. hospitals	Percent represented by sample
Number of hospitals	50	1,045	[1]2,209	[2]47
Number of births	134,118	2,533,415	[1]3,002,232	[2]84.4
Total births	[5]118,771	2,533,415	[3]3,760,516	67.4
Number of low-birth-weight births	11,442	179,734	[3,4]223,196	80.5
Ratio	9.6	7.1	5.9	—

[1]From urban hospitals with obstetrical departments.
[2]Urban hospitals.
[3]From all U.S. births.
[4]Based on Hogue, C.J., Buehler, J.W., Strauss, L.T., and Smith, J.C.: Overview of the National Infant Mortality Surveillance Project—Design, Methods, Results. *Public Health Reports* 102:126-138, Mar.-Apr. 1987; data inflated to 1985 levels.
[5]Cases with birth-weight data available.

SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

Table 3

Pediatric modified diagnosis-related groups (PMDRGs) for newborns (version 5.0)

PMDRG	Description
601	Neonate, died within 1 day of birth, born here
602	Neonate, died within 1 day of birth, not born here
603	Neonate, transfer < = 4 days old, born here
604	Neonate, transfer < = 4 days old, not born here
605	Neonate, back referral for aftercare
611	Neonate, birth weight < 750G, DMV > 21 days, discharged alive
612	Neonate, birth weight < 750G, DMV< = 21 days, discharged alive
613	Neonate, birth weight < 750G, died
621	Neonate, birth weight 750-999G, DMV > 21 days, discharged alive
622	Neonate, birth weight 750-999G, DMV 4-21 days discharged alive
623	Neonate, birth weight 750-999G, DMV < 4 days, discharged alive
624	Neonate, birth weight 750-999G, died
631	Neonate, birth weight 1000-1499G, with significant OR procedure, DMV > 21 days, discharge alive
632	Neonate, birth weight 1000-1499G, with significant OR procedure, DMV 4-21 days, discharge alive
633	Neonate, birth weight 1000-1499G, with significant OR procedure, DMV < 4 days, discharge alive
634	Neonate, birth weight 1000-1499G, without significant OR procedure, DMV > 21 days, discharge alive
635	Neonate, birth weight 1000-1499G, without significant OR procedure, DMV 4-21 days, discharge alive
636	Neonate, birth weight 1000-1499G, without significant OR procedure, < DMV 4-21 days, discharge alive
637	Neonate, birth weight 1000-1499G, died
641	Neonate, birth weight 1500-1999G, with significant OR procedure, DMV > = 4 days
642	Neonate, birth weight 1500-1999G, with significant OR procedure with multiple major problems
643	Neonate, birth weight 1500-1999G, with significant OR procedure without multiple major problems
644	Neonate, birth weight 1500-1999G, without significant OR procedure, DMV > = 4 days
645	Neonate, birth weight 1500-1999G, without OR procedure, with multiple major problems
646	Neonate, birth weight 1500-1999G, without significant OR procedure with major problems
647	Neonate, birth weight 1500-1999G, without significant OR procedure without major problems
651	Neonate, birth weight 2000-2499G, with significant OR procedure, DMV > = 4 days
652	Neonate, birth weight 2000-2499G, with significant OR procedure, with multiple major problems
653	Neonate, birth weight 2000-2499G, with significant OR procedure without multiple major problems
654	Neonate, birth weight 2000-2499G, without significant OR procedure, DMV > = 4 days
655	Neonate, birth weight 2000-2499G, without significant OR procedure, with multiple major problems
656	Neonate, birth weight 2000-2499G, without significant OR procedure, with major problems
657	Neonate, birth weight 2000-2499G, without significant OR procedure, with minor problems
661	Neonate, birth weight < 2499G, with significant OR procedure, DMV > = 4 days
662	Neonate, birth weight > 2499G, with significant OR procedure, with multiple major problems
663	Neonate, birth weight > 2499G, with significant OR procedure, without multiple major problems
664	Neonate, birth weight > 2499G, with minor abdominal procedure, with multiple major problems ≥ 4 days
665	Neonate, birth weight > 2499G, with minor abdominal procedure, without multiple major problems
666	Neonate, birth weight > 2499G, without significant OR procedure, > = 4 days
667	Neonate, birth weight > 2499G, without significant OR procedure, with multiple major problems
668	Neonate, birth weight > 2499G, without significant OR procedure, without major problems
669	Neonate, birth weight > 2499G, without significant OR procedure, with minor problems
671	Neonate, birth weight 2000-2499G, without significant OR procedure, with minor problems
672	Neonate, birth weight 2000-2499G, without significant OR procedure, with only normal newborn diagnosis
673	Neonate, birth weight > 2499G, without significant OR procedure, with other problems
674	Neonate, birth weight > 2499G, without significant OR procedure, with only normal newborn diagnosis

NOTES: DMV is days with mechanical ventilation. OR is operating room. G is gram.

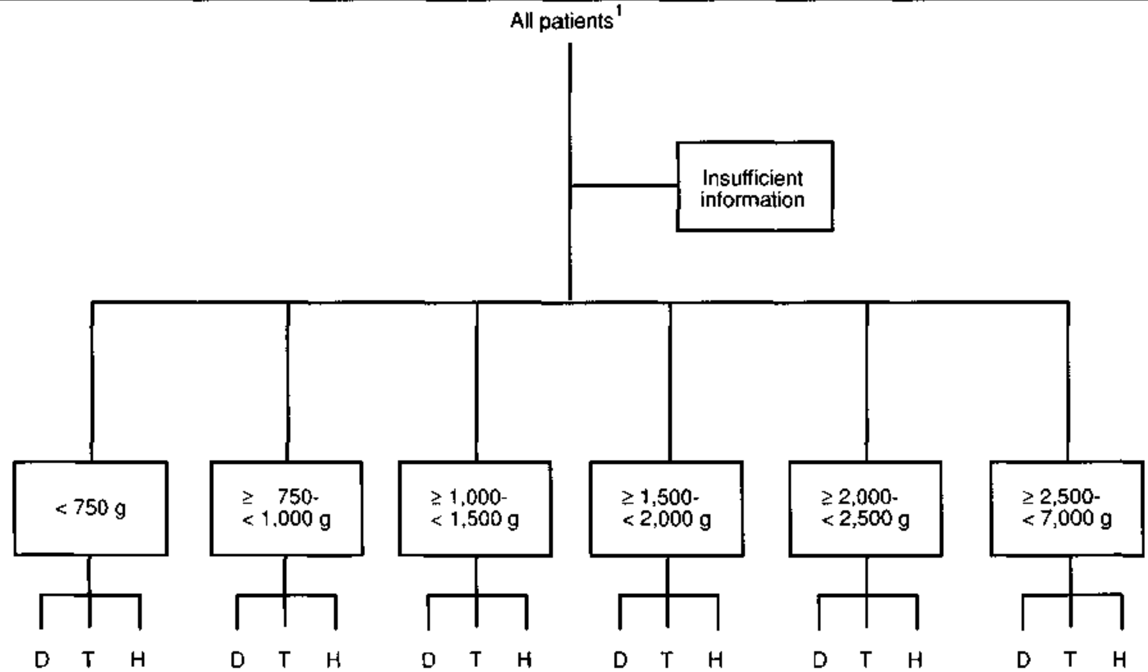
SOURCE: National Association of Children's Hospitals and Related Institutions, Alexandria, Virginia, 1986.

all non-normal neonates (Table 2). Infants who died or were transferred were placed in DRG 385. DRG 386 includes those with the ICD-9-CM code for extreme immaturity or respiratory distress syndrome. DRGs 387 and 388 are for premature infants with and without major problems, respectively, and 389 includes full-term newborns with major problems. DRG 390 (full-term neonates with other problems) includes less sick infants with minor problems. DRG 391 (normal newborn) includes only those newborns who are completely normal.

As already noted, the DRGs have been criticized for grouping heterogeneous cases together. This criticism arises from the failure of DRGs to distinguish between surgical and medical cases or to distinguish between cases ending in transfer or death. DRGs also do not reflect differences in birth weight or handling of complications. Although transfers represent a small group of newborns, there are four categories of neonatal transfer in regionalized neonatal care: transfers into tertiary hospitals (regional referrals for complex care); transfers into community hospitals or return transports for convalescent care; transfers out of tertiary hospitals (return transports); and transfers out of community hospitals (regional referrals for complex care). Thus, both admission and discharge status, as well as type of facility, are all relevant. DRGs focus only on discharge status. A final source of confusion is that major diagnostic category (MDC) 15 does not include all admissions of patients under 28 days of age, so a small percentage of newborns are scattered across many DRGs outside of MDC 15.

The PMDRGs were developed by NACHRI to provide within-DRG homogeneity for patients 0-17 years of age. The PMDRG plan (version 5.0) includes an extensive revision of the 7 neonatal DRGs, with an expansion of the number of categories to 46 (Table 3). The PMDRGs reflect six birth-weight groups, the presence or absence of a significant procedure; the presence or absence of a major problem; whether or not the patient lived or died;

Figure 1
Grouping scheme based on discharge status and birth weight only



[1] 0-28 days old.
NOTES: D is died. T is transferred. H is home. G is grams.
SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

and (for cases ending in death or transfer after a 1 to 4-day stay) whether the patient was born in the reporting hospital or a different one. Finally, the use of mechanical ventilation was added as a discriminator among groups. There are 14 PMDRGs in which "days of mechanical ventilation" is a determinant of the category into which the case is placed. Our data set did not include information on mechanical ventilation, so cases are treated as though no mechanical ventilation was provided. In a subsequent analysis using a smaller hospital data set not presented here, mechanical ventilation information was added, but the findings revealed no major improvement in explanatory power (Payne and Schwartz, 1991).

Besides DRGs and PMDRGs, patients were also classified into a third schema called BWDIS developed by the authors. In this scheme, the same birth-weight categories from PMDRGs were used in combination with discharge status only. The BWDIS model is entirely objective, relying only on the birth weight and status of the patient at discharge (home, died, transferred). The BWDIS grouping scheme (Figure 1) is in essence a "stripped-down" version of PMDRGs and was used to determine how well resource use can be predicted in the absence of any diagnostic data.

Analytic data set

Prior to the analysis, all patients identified as normal newborns were excluded, i.e., patients placed in the "normal" category of both DRGs and PMDRGs were dropped from the analysis. There were 75,001 such cases. In addition, consistent analysis could be performed only on cases with sufficient data to be grouped using both PMDRGs and DRGs. Because PMDRGs require birth-weight information, all cases missing such data (14,606 cases) were eliminated. In an analysis of these cases, we identified these newborns as sicker than those remaining in the study, as measured by both average cost per case and average length of stay. Although this could affect the comparability of our findings with analyses done with birth weight available for all cases, our study is based on the only single-year national multihospital data file with birth-weight data; this includes more than 43,500 non-normal neonates.

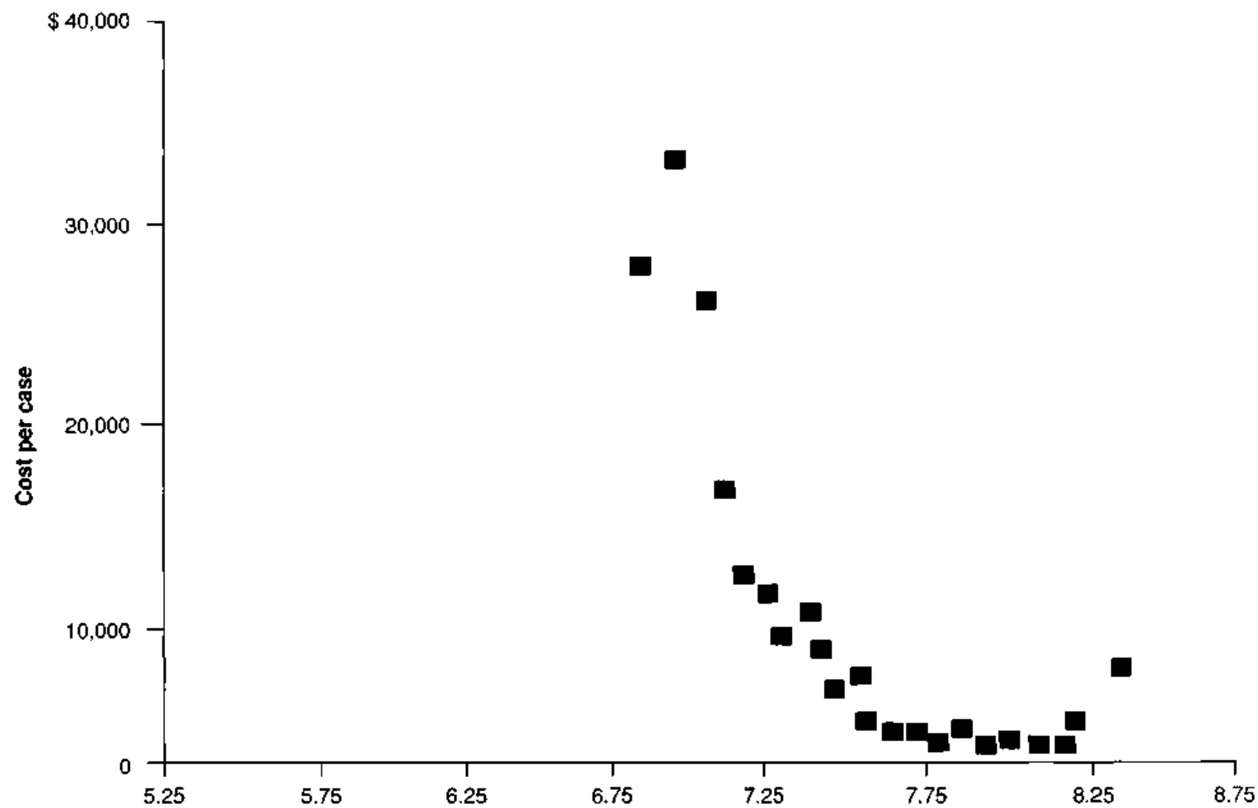
A major difference between PMDRGs and DRGs is that the former includes all non-normal newborns within the neonatal major diagnostic category (MDC 15). The DRGs allow for a scattering of cases across many DRGs outside of MDC 15. To simplify the analysis, neonates outside MDC 15 were then included in one category labeled DRG 392. This was done because there were 2,507 cases (1.8 percent of all cases) falling into 190 separate DRGs. Only 14 of these DRGs had more than 50 cases (across all hospitals). When birth weight was required, the resulting case file was reduced to 1,012 cases in DRG 392, or 2.3 percent of the analytic file. The implication for the analytic results is to slightly exaggerate the improvement in explained variation for PMDRGs over DRGs.

Analysis

The analytic models presented herein examine cell size and explanatory power of the DRGs, the PMDRGs, and

Figure 2

Relationship between birth weight and cost per case for diagnosis-related group 388



SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

the simplified grouper (BWDIS) using birth weight and discharge status only. We then explore a new model using birth weight as a continuous function in combination with DRGs.

The basis of our new model is the strong relationship between birth weight and resource consumption. Preliminary correlations identified that birth weight explained 16 percent of the variation in length of stay for all patients. Plotting the data (averaged at 100-gram intervals), as shown in Figure 2, confirmed a curvilinear relationship that was similar across all non-normal DRGs except DRG 385, which includes infants who die or are transferred. The data plot in Figure 3 shows that, for those who die, there is no relationship between birth weight and cost per case (correlation analysis showed an r^2 of .00). Transferred cases showed a weak relationship (r^2 of .09). This finding was used to refine the basic model.

The mathematical form of the basic model called BWADJ is based on the empirical observation that cost and length of stay tend to be minimal for patients with birth weights around 3,200 grams. These models therefore contain an expression of the form:

$$\left[BW - \left(\frac{BW}{80}\right)^2\right]$$

which, if multiplied by a negative coefficient, minimizes the function when BW is equal to 3,200.

Using the DRG-independent functions:

$$\text{Length of stay or cost} = a + b\left[BW - \left(\frac{BW}{80}\right)^2\right]$$

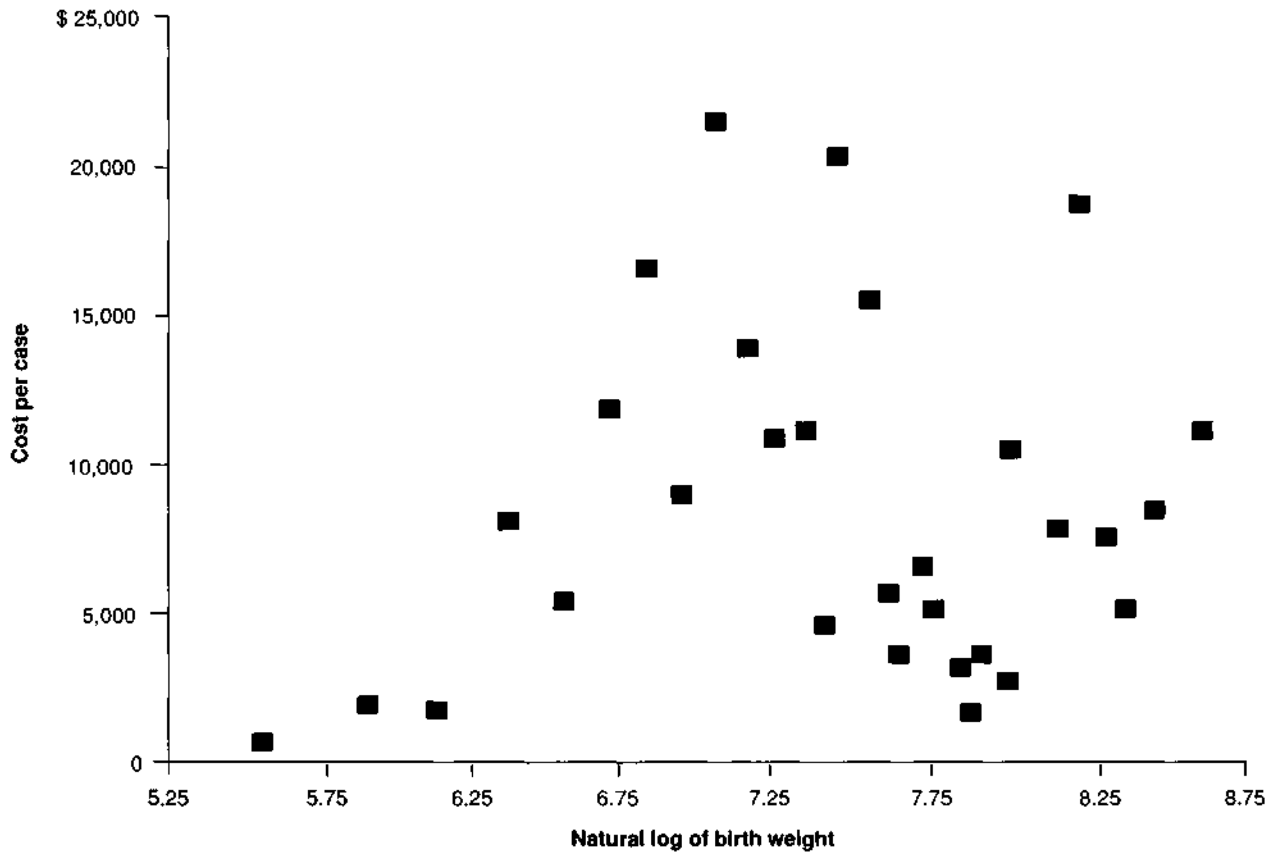
for all patients who went home, and fitting the two adjustable parameters a and b to our patient data by the method of least-squares, 21 percent of the length-of-stay (LOS) variance and 19 percent of the cost variance was explained.

This function was generalized to create equations maximizing the explained variation in cost per case controlling for DRG. By letting the a and b parameters be DRG-specific, we obtained the model called DRGADJ:

$$\text{Cost or length of stay} = a\text{DRG} + b\text{DRG}\left[BW - \left(\frac{BW}{80}\right)^2\right]$$

where DRG can take a value between 385 and 391 and aDRG + bDRG are fitted to our patient data by least

Figure 3
Relationship between birth weight and cost per case for newborns in diagnosis-related group 385 who die



SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

squares. For payment purposes, such a model would be used to pay a base amount by DRG and adjust this amount depending on the infant's actual birth weight in grams. Because cost decreases as weight increases, the birth-weight term is negative.

The refinement of the DRGADJ model was based on our knowledge that newborns who die have different resource consumption patterns unrelated to birth weight. Because relatively few infants expire (1.2 percent of the original data base) and because of the apparent randomness of resource consumption for these newborns (Figure 3), the model was modified to identify the impact of paying for patients who die based on length of stay. This second model is called DRGADJ+D. The continuous-function models were developed and tested on only one data set. As a result, findings presented here are not strictly comparable with the findings for DRGs, PMDRGs, and the BWDIS model. The findings do, however, identify a method that makes maximal use of two powerful pieces of information—discharge status and birth weight.

Results

Cell size

By expanding the number of DRG categories from 7 to 31, as in the PMDRG model (without the mechanical ventilation groups), or even to 18, as in the BWDIS model, the number of categories could create a problem of small cell size. In Table 4, the grouping schemes are compared with regard to small cell size. The data show that both PMDRGs and the BWDIS model would have small cells for 63 to 55 percent of cells in the non-tertiary hospitals. As such, these hospitals could expect to have as many as 22 PMDRG groups with 3 or fewer patients (on average). The PMDRGs were not designed for non-tertiary hospitals and, as such, this finding might be expected. Tertiary hospitals, however, which would be expected to care for the most high-risk infants, also had a large number of cells with few cases. Using the PMDRGs, there are 13 groups in which tertiary hospitals would have 3 or fewer cases on average, per hospital. Even the BWDIS model shows four categories in tertiary hospitals that would have fewer than three cases. The

Table 4

Comparison of the number of case-mix groups with small cells for 3 models

Model	All hospitals (N = 50)				Tertiary hospitals (N = 28)				Non-tertiary hospitals (N = 22)			
	Less than 150 cases		Less than 50 cases		Less than 150 cases		Less than 50 cases		Less than 150 cases		Less than 50 cases	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
DRG[1]	0	0	0	0	0	0	0	0	0	0	0	0
PMDRG[2]	11	34.4	5	15.6	13	40.6	5	15.6	22	62.8	15	46.8
BWDIS[3]	3	16.7	1	5.6	4	22.2	2	11.1	10	55.5	6	33.3

[1]Model has 7 groups (excluding non-neonatal DRGs).
[2]Model has 32 groups (excluding non-neonatal PMDRGs and PMDRGs for days with mechanical ventilation).
[3]Model has 18 groups.

NOTES: DRG represents the model based on diagnosis-related groups; PMDRG represents the model based on pediatric modified diagnosis-related groups; BWDIS represents the model based on birth-weight and discharge status.

SOURCE: Schwartz, R.M., Michelman,T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

non-tertiary hospitals have an even greater number of cells with small numbers of cases in the BWDIS model compared with the PMDRG model.

Regression analysis

Regressions were performed using all three grouping schemes and two models using birth weight (DRGADJ and DRGADJ+D). Table 5 shows the results for the dependent variables length of stay and cost per case for DRGs, PMDRGs, and BWDIS. We also examined the log of the length-of-stay charges and cost per day but found these analyses did not contribute any additional understanding of the models. (These findings are not presented.)

The DRG model performed poorly, as already indicated by other researchers. It accounted for 22.6 percent of the variation in length of stay and 19.4 percent of the variation in cost. The PMDRGs performed exceptionally well, explaining 48.7 percent of the variation in length of stay and 43.2 percent of the variation in cost. The BWDIS model performed much better than the DRGs on both length of stay and cost, but not nearly as well as the PMDRGs, explaining 40.4 percent of the variance in length of stay and 32.6 percent of the variance in cost per case.

Table 6 presents the findings for the DRGADJ and DRGADJ+D models. The DRGADJ model, which uses the curvilinear function in combination with the DRGs, explained 45.9 percent for length of stay and 37.9 percent for cost per case, compared with 22.6 and 19.4 percent in the original DRG model. If the DRGADJ model were to be introduced into a payment plan, the DRG categories would remain the same but each case would receive a payment adjustment based on birth weight.

Table 5

Comparison of the explained variance for length of stay and cost using 3 case-mix grouping approaches

Case-mix grouping	Length of stay (r^2)	Cost per case (r^2)
DRG	.226	.194
PMDRGs	.487	.432
BWDIS[1]	.404	.326

[1]BWDIS model has 18 categories based on birth weight and discharge status alone.

NOTES: DRG is diagnosis-related group. PMDRG is pediatric modified diagnosis-related group.

SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

Because birth weight does not predict costs for neonates who die, the model was further refined to reflect the costs for these newborns. The model DRGADJ+D breaks down DRG 385 (which includes both neonates who die and those who are transferred) into these two categories. The model used length of stay instead of the birth-weight function for those who died. The regression analysis using this model reveals that 57.4 percent of the variation in length of stay and 51.3 percent of the variation in cost per case is explained. As Table 6 shows, the DRGADJ+D model yields a substantial improvement over the DRGADJ model. Although our findings are not strictly comparable to the PMDRG model, there is evidence that birth weight and discharge status in combination with DRGs can explain resource consumption as effectively as an approach using many categories.

Table 7 shows that if we examine the tertiary and non-tertiary settings separately, we find that grouping schemes do not function as well for non-tertiary settings. This is as expected, because the degree of variation in case mix found in tertiary hospitals is not present. However, in selecting a grouping scheme, the goal should be to do as well as possible in subgroups of hospitals to avoid the possibility of favoring one group over another. The analyses show that PMDRGs are much more successful in explaining variation in the non-tertiary hospital group compared with the DRG and BWDIS classification schemes. Although the two models that use the continuous birth-weight function are developmental in nature, we can see that the DRGADJ+D model explains more variation except for length of stay in non-tertiary settings (.447 compared with to .452). It is important to note, however, that the PMDRGs have the least disparity among the tertiary and non-tertiary groups even though DRGADJ+D has higher r^2 values.

Table 6
Regression estimates for 2 models using diagnosis-related groups (DRGs) and the continuous birth-weight function

Dependent or independent variable	Length of stay Beta	Length of stay Standard error	Cost Beta	Cost Standard error
Parameters of model DRGADJ				
DRG 385	*5.55	0.45	*8,693.77	319.18
Birth-weight term for DRG 385	*–.004	1.28	*–4.23	0.086
DRG 386	*122.7	0.48	*73,937	328.4
Birth-weight term for DRG 386	*–.079	1.70	*–47.21	0.12
DRG 387	91.31	0.54	*43,483.02	370.87
Birth-weight term for DRG 387	*–.061	2.41	*–28.74	0.16
DRG 388	*58.63	0.72	*23,023.00	489.11
Birth-weight term for DRG 388	*.041	3.91	*–15.92	0.27
DRG 389	*11.74	0.55	*5,691.59	375.11
Birth-weight term for DRG 389	*–.010	2.25	*–4.29	0.15
Birth-weight term for DRG 390	*–.003	2.77	*–1.00	0.18
DRG 391	.08	0.75	616.47	512.99
Birth-weight term for DRG 391	*–.003	4.23	*–1.38	0.29
DRG 392	*55.5	1.08	*49,963.00	737.28
Birth-weight term for DRG 392	*–.04	6.51	*–31.00	0.44
Constant	*2.13	0.027	*2,185.96	292.14
r^2	.459		.379	
Parameters of model DRGADJ + D				
DRG 385 DLOS	*1.00	0.002	*683.12	1.58
DRG 385 died	*–8.81	0.39	*–1,092.65	263.82
DRG 385 transferred	*29.33	0.49	*21,681.56	330.56
Birth-weight term for DRG 385	*–0.02	2.25	*–14.22	0.15
DRG 386	*122.7	0.43	*73,937.00	290.96
Birth-weight term for DRG 386	*–0.08	1.51	*–47.21	0.10
DRG 387	*91.31	0.48	*43,483.02	328.51
Birth-weight term for DRG 387	*0.06	2.14	*–28.74	0.14
DRG 388	*58.63	0.64	*23,028.00	433.24
Birth-weight term for DRG 388	*–0.041	3.47	*–15.92	0.23
DRG 389	*11.74	0.49	*5,691.59	332.29
Birth-weight term for DRG 389	*0.01	2.00	*4.29	0.13
Birth-weight term for DRG 390	*–0.003	2.46	*1.00	0.16
DRG 391	*0.08	0.62	*616	0.45
Birth-weight term for DRG 391	*–0.003	3.75	*–1.38	0.25
DRG 392	*55.54	0.96	*49,963.00	653.00
Birth-weight term for DRG 392	0.04	5.77	*–31.00	0.39
Constant	8.82	0.38	2,185.96	258.77
r^2	.573		.513	

*$P < .0001$.

NOTES: DRGADJ represents the model based on DRGs with an adjustment for birth weight. DRGADJ + D represents the model based on DRGs adjusted for birth weight and stays ending in death. DLOS represents length of stay for those who died.

SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs,C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

Table 7
Regression analysis for length of stay and cost for tertiary and non-tertiary hospitals, by payment model

Model	R^2 for length of stay: Tertiary	R^2 for length of stay: Non-tertiary	R^2 for cost: Tertiary	R^2 for cost: Non-tertiary
DRG	.250	.105	.231	.105
PMDRG	.497	.452	.456	.300
BWDIS	.436	.355	.375	.191
DRGADJ	.478	.397	.420	.195
DRGADJ+D	.606	.447	.561	.311

NOTES: DRG represents the model based on diagnosis-related groups. PMDRG represents the model based on pediatric modified diagnosis-related groups. BWDIS represents the model based on birth weight and discharge status. DRGADJ represents the model based on DRGs with an adjustment for birth weight. DRGADJ+D represents the model based on DRGs adjusted for birth weight and stays ending in death.

SOURCE: Schwartz, R.M., Michelman, T., Pezzullo, J., and Phibbs, C.: National Perinatal Information Center, Providence, Rhode Island, 1989.

Discussion

By dividing cases into more and more refined categories, one can classify non-normal neonates into case-mix groups that are homogeneous across groups of hospitals. However, as is the case with PMDRGs, such an approach can create a large number of categories with few cases in some categories. Admittedly, these groups appear to explain a great deal of variation in both cost and length of stay, but there is a tradeoff between greater explained variation and large numbers of small cells. Payment systems that are based on averages must be sensitive to the presence at the hospital level of enough cases to balance losses against gains—cells with few cases do not allow this.

The BWDIS model, which uses only birth weight and discharge status, though simpler, has similar problems. Interestingly, the BWDIS model regressions reveal that the current DRGs can be easily improved without using any diagnostic information. The BWDIS model shows that birth weight and discharge status alone are more powerful in explaining variation in length of stay and cost per case than the sophisticated algorithms for sorting diagnostic information used in the current DRG model. This unexpected finding essentially highlights just how poorly the neonatal DRGs perform in the current configuration.

The use of the birth-weight function as a DRG adjuster is one improvement that would not require additional groups. In addition, it is entirely objective. Babies are weighed, the birth weight is recorded in the medical record, and, in most locations, on the birth certificate; further, at the time of birth or recording there is virtually no possibility of fabrication because parents and physicians sign the birth certificate. Although this information is not routinely on the discharge abstract or bill information, it can be easily added. There are three States, Connecticut, Maryland, and New York, that include birth weight on the discharge abstract. Birth weight as a continuous variable offers a unique severity indicator for newborns.

Interestingly, the models improve substantially when care for infants who die is paid for based on length of stay prior to death (DRGADJ+D). As shown in Figure 3, birth weight is not a meaningful predictor of cost for infants who die, even though it is a predictor of who dies. But would payment based on length of stay create incentives to keep patients alive for payment? We might ask the converse as well: Would DRG 385, which has an unusually short geometric mean length of stay (3.7 days) and low payment weight (1.22) create an incentive to allow very sick infants to die more quickly for lack of payment? These may be equally unattractive, but the current Medicare DRG payment system has already selected the latter. These authors would argue that, as there is no good or ideal payment alternative, the system should, at a minimum, eliminate the smorgasbord of patients in DRG 385 by separating those who die from those who are transferred. The birth-weight parameter could then be used for the transfer cases and length of stay for those who die.

Transferred cases still fall into two separate categories, those transferred to a perinatal center from a community hospital for tertiary care and those transferred to a community hospital from a perinatal center for convalescent care. Further refinements to recognize this difference in the DRGAJD+D model would be important prior to its use for payment. Finally, the DRGs have been criticized for their clinical meaningfulness because of the way in which ICD-9-CM codes are used. Our approach does not address this issue.

Payment policy is moving quickly toward case-based payments using patient classification. Although the aim of such systems is to explain resource consumption accurately through grouping, Medicare and Medicaid both rely on other factors for adjusting payment. Medicare has adjustments that include the location of the hospital; the wage index of the area; teaching intensity; the proportion of patients receiving supplemental security income or Medicaid; and capital cost allocations. The weights assigned to the groups and the determination of the outlier cutoff points play a major role in whether or not a specific hospital or group of hospitals receives sufficient payment to cover the cost of care for patients within a DRG. Financial impact analyses were performed as part of the primary research from which this presentation is drawn (Schwartz, 1989); these analyses showed that equity in payment across tertiary and non-tertiary hospitals can only be accomplished if the underlying case-mix grouping accurately explains resource consumption in both tertiary and non-tertiary hospitals. Our point, however, is that DRGs perform poorly for both groups of hospitals, implying that the clinical meaningfulness of the grouping mechanism is highly questionable. As a result, we must focus not on whether improvement is required but on how it should be accomplished.

We have shown through the BWDIS grouping that it is easy to outperform DRGs for neonates. The approach of least resistance is to create more groups when squarely facing the fact that DRGs as they stand do not successfully explain variation in resource consumption. However, we have at our disposal two powerful and easily accessible variables that can be used to improve explanatory power: birth weight and discharge status. The use of a continuous birth-weight adjustment for DRGs to better reflect case mix will allow the current payment method to more accurately reflect severity and thereby pay for care in a more precise manner. Such an approach does not create many categories or rely on procedures to improve accuracy.

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References

American Hospital Association: Annual Survey of Hospitals. Chicago. 1984.

Avery, M.E., Tooley, Keller, J., et al.: Is chronic lung disease in low birth weight infants preventable? A survey of eight centers. *Pediatrics* 79(1):26-30, 1987.

Berki, S.E., and Scheier, N.B.: Frequency and cost of diagnosis-related group outliers among newborns. *Pediatrics* 79(6):874-881, June 1987.

Federal Register: Vol. 52, No. 169, 33110. Office of the Federal Register, National Archives and Records Administration. Washington. U.S. Government Printing Office, Sept. 1, 1987.

Public Health Service and Health Care Financing Administration: *International Classification of Diseases, 9th Revision, Clinical Modification.* DHHS Pub. No. 80-1260. Public Health Service. Washington. U.S. Government Printing Office, Sept. 1980.

Lichtig, C.K., and Kannf, R.A.: Revising diagnosis related groups for neonates. *Pediatrics* 84(1):61, July 1989.

Payne, S.M., and Schwartz, R.M.: Developing and evaluating options for pediatric prospective payment systems. Final report prepared for the Health Care Financing Administration. Boston. Health Care Evaluation Unit of Boston University, Feb. 1991.

Phibbs, C.S., Phibbs, R.H., Pomerance, J.J., and Williams, R.L.: Alternative to diagnosis related groups for newborn intensive care. *Pediatrics* 78(5):829-836, Nov. 1986.

Poland, R.L., Bollinger, R.O., Bedard, M.P., and Cohen, S.N.: Analysis of the effect of applying federal diagnosis-related grouping (CDRG) guidelines to a population of high-risk newborn infants. *Pediatrics* 76(1):104-109, July 1985.

Resnick, M.B., Ariet, M., Carter, R.L., et al.: Prospective pricing system for tertiary neonatal intensive care. *Pediatrics* 78(5):820-828, Nov. 1986.

Schwartz, R.M.: What price prematurity? *Family Planning Perspectives* 21:170-174, Aug. 1989.

Schwartz, R.M., Gagnon, D.E., Muri, J.H., and Michelman, T.S.: The Impact of DRG Based Reimbursement on Perinatal Regionalization. Report prepared for Division of Maternal and Child Health, U.S. Department of Health and Human Services. Providence, RI. National Perinatal Information Center, Aug. 31, 1989.

Simborg, D.W.: DRG creep: A new hospital acquired disease. *New England Journal of Medicine* 304(26):1602-1604, June 25, 1981.

Yale University Health System Management Group: DRG Refinement with Diagnostic Specific Co-morbidities and Complications: A Synthesis of Current Approaches to Patient Classification. Final report prepared for the Health Care Financing Administration. Feb. 1989.