Using Economic Information in a Quality Improvement Collaborative

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ABSTRACT. This article provides an overview of neonatal intensive care unit treatment costs for hospitals that participated in the Neonatal Intensive Care Quality Improvement Collaborative Year 2000 (NIC/Q 2000) quality improvement collaborative and discusses how economic information can be used in quality improvement efforts. Detailed information on neonatal intensive care unit treatment costs is presented for 29 hospitals that participated in the NIC/Q 2000 collaborative. The sample consists of 6797 very low birth weight infants (1500 g or less at birth) with admission dates between January 1, 1997, and December 31, 1998. Information on median treatment cost per infant, ancillary costs, accommodation costs, length of stay, and cost per day is presented. In addition, ancillary costs are further disaggregated into those for respiratory therapy, laboratory, radiology, pharmacy, and all other ancillary services. The role of level of care and other factors that influence treatment costs are then explored. *Pediatrics* 2003;111:e411–e418. URL: http://www.pediatrics.org/cgi/content/full/111/4/e411; *NICU cost, VLBW cost, collaborative quality improvement, NIC/Q 2000.*

ABBREVIATIONS. NIC/Q 2000, Neonatal Intensive Care Quality Improvement Collaborative Year 2000; NICU, neonatal intensive care unit.

KEY POINTS OF ARTICLE

- Treatment costs for very low birth weight infants are high.
- Quality improvement efforts may alter treatment costs in either direction.

APPLYING LESSONS LEARNED TO PRACTICE

- Important factors to consider when benchmarking economic performance include mix of patients, birth weight, gestational age, survival, and type of unit.

Advances in neonatal technology in the past decades have significantly improved survival prospects for infants who are born prematurely, but these improvements have come at a high cost. Neonatal intensive care stays are among the most expensive types of hospitalizations.[1] Quality improvement efforts will affect treatment costs because they will alter, in some way, the resources used in patient care. A study of a recent collaborative quality improvement effort in neonatology[2] demonstrated that significant cost savings may accrue from quality improvement efforts in high-cost patient populations. In this study, each dollar spent on quality improvement in neonatal intensive care yielded $9 in savings in treatment costs during the postintervention year.[2]

This article discusses treatment costs for neonatal intensive care units (NICUs) that participated in the Neonatal Intensive Care Quality Improvement Collaborative Year 2000 (NIC/Q 2000) collaborative for quality improvement, with a focus on how economic information can be used to inform quality improvement efforts. Information on the magnitude of treatment costs for infants with very low birth weight varies among hospitals in the collaborative. Treatment costs are disaggregated into their major components, including accommodation costs and ancillary costs (respiratory therapy, laboratory, radiology, pharmacy, and all other ancillary services). The article then discusses how information on treatment costs can be used to understand economic performance of a unit and to inform quality improvement efforts.

DATA

Thirty-four hospitals participated in the NIC/Q 2000 collaborative quality improvement project. Of these, 32 provided data on treatment costs for the study's preintervention period, 1997 to 1998. Among the hospitals that submitted data, 3 provided data that were either incomplete or of poor quality and were excluded from these tabulations. Data are presented for 6797 infants with very low birth weight (1500 g and under) from 29 hospitals in the NIC/Q 2000 collaborative.

Hospitals submitted UB-92 billing data for each very low birth weight infant in their Vermont Oxford Network database. The hospital billing data consists of hospital charges. These charges were converted to measures of treatment costs using cost-to-charge ratios from hospital cost reports submitted to the Centers for Medicare and Medicaid Services (CMS). The cost report is a standard financial reporting form generated each year by hospitals as part of reporting requirements imposed by the Centers for Medicare and Medicaid Services (form HCFA-2552). A detailed description of the cost conversion methodology can be found in a recent article on measuring treatment costs for neonatal intensive care.[3] The advantage of using measures of treatment cost created in this manner is that they are independent of differences in pricing across hospitals and thus uniform across institutions. All dollar amounts are converted

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into 1998 constant dollars using the medical component of the consumer price index as generated by the Bureau of Labor Statistics.[4] Information on treatment costs is reported using median values instead of mean values because of the long right tails in cost data. Median values are less sensitive to large cost outliers than means and therefore provide a better basis on which to judge economic performance.

TREATMENT COSTS IN THE NIC/Q 2000 COLLABORATIVE

Costs of care for very low birth weight infants among hospitals in the NIC/Q 2000 collaborative are presented in Table 1. Overall, the median treatment cost per infant for infants with birth weight 1500 g and under was $53 300 for hospital care. The median length of stay was 47 days with a median cost per day of $1250. The majority of treatment costs, an average of $37 700, are associated with accommodations. An additional $14 300 in costs is accounted for by ancillary services.

In interpreting information on treatment costs at the unit level, it is important to consider the factors that influence treatment costs. Important among these considerations is the mix of patients in the unit. As shown in Table 1, treatment costs vary widely by birth weight. Thus, the birth weight mix of infants in a unit will affect the average level of treatment costs. Infants with birth weights between 501 and 750 g are the most expensive to care for, with median treatment costs of $103 600. Treatment costs drop as birth weight increases. Thus, whereas infants with birth weight between 751 and 1000 g have median treatment costs of $79 400, for those in the highest birth weight range (1251–1500 g), costs are less than half as much, $31 200. Treatment costs are lowest for infants with birth weight <500 g, largely because these infants have high mortality rates, as reflected in an average length of stay of 2 days. In the sample of infants from the 29 NIC/Q 2000 hospitals, 2% have birth weight <500 g, 19% have birth weight 501 to 750 g, and approximately one quarter have birth weight in each of the higher 250-g birth weight ranges. A unit that has a different birth weight distribution than the average should expect to have different treatment costs. For instance, a unit with a disproportionately high number of infants in the 501- to 750-g range will have higher treatment costs as a result of the mix of patients treated.

Differences in overall treatment costs are attributable to a combination of differences in length of stay and intensity of care, as measured by treatment cost per day. For infants with birth weight >500 g, both length of stay and cost per day drop as birth weight rises. For instance, infants with the highest overall treatment cost per infant (in the 501- to 750-g range) also have the highest median length of stay, 81 days, and treatment cost per day, $1640. Both length of stay and cost per day drop by 20% in the next highest birth weight range (751–1000 g) to 66 days and $1330 per day, respectively. For very low birth weight infants in the highest birth weight range, 1251 to 1500 g, length of stay is again half as high, 32 days. Treatment intensity, as measured by cost per day, is lower but only by 20% ($1050 per day).

Table 2 provides some insights into differences in ancillary costs by birth weight. Median ancillary costs are $14 300. These costs are also inversely related to birth weight for birth weights >500 g. For instance, for infants in the 501- to 750-g range, median costs are $34 400, compared with only $6000 for infants in the 1251- to 1500-g range, a 5-fold difference in magnitude. Respiratory therapy costs differ dramatically by birth weight. The highest median value is for infants with birth weight between 501 and 750 g, $9200. In contrast, respiratory therapy costs for the next highest birth weight range are one third lower ($6100). For infants in the 1001- to 1250-g

TABLE 1. Median Treatment Costs for Very Low Birth Weight Infants (1997-1998)*

Category	*N*	%	Total Cost	Accommodation Cost	Ancillary Cost	LOS	Cost Per Day
Overall	6797		53 316	37 723	14 328	47	1249
Birth weight							
<500 g	166	2.4	8062	1932	4715	2	1350
501–750 g	1298	19.1	103 637	62 929	34 386	81	1643
751–1000 g	1662	24.5	79 376	52 443	23 939	66	1333
1001–1250 g	1788	26.3	50 127	36 076	12 437	47	1154
1251–1500 g	1883	27.7	31 226	24 273	6032	32	1051
Gestational age							
<24 wk	249	3.7	8556	2105	6250	2	1783
24–26 wk	1739	25.6	101 638	64 978	33 495	79	1565
27–29 wk	2501	36.8	62 960	43 489	17 159	55	1236
30–32 wk	1833	27.0	34 258	26 562	6853	36	1044
>32 wk	475	7.0	18 676	15 550	3144	22	959
Location of birth							
Inborn	5433	79.9	52 745	37 969	13 384	48	1201
Outborn	1364	20.1	56 215	35 972	18 903	43	1494
Survival status							
Died day 1	186	2.7	1983	850	1085	1	1910
Died after day 1	640	9.4	18 041	6515	10 900	7	2619
Transfer	1264	18.6	41 830	28 103	12 314	29	1497
Home	4707	69.3	63 789	45 226	16 482	57	1140

LOS indicates length of stay.
N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network.
* All dollar figures are in constant (1998) dollars.

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TABLE 2. Median Ancillary Costs for Very Low Birth Weight Infants (1997-1998)*

Category	*N*	%	Total Ancillary	Respiratory	Laboratory	Radiology	Pharmacy	Other Ancillary
Overall	6797		14 328	2752	2743	752	2892	3215
Birth weight								
<500 g	166	2.4	4715	767	1074	379	1102	868
501–750 g	1298	19.1	34 386	9243	6839	1790	5591	6575
751–1000 g	1662	24.5	23 939	6124	4662	1233	4416	4901
1001–1250 g	1788	26.3	12 437	2252	2342	629	2754	2921
1251–1500 g	1883	27.7	6032	844	1185	345	1321	1645
Gestational age								
<24 wk	249	3.7	6250	810	1480	520	1357	1262
24–26 wk	1739	25.6	33 495	8865	6564	1733	5706	6349
27–29 wk	2501	36.8	17 159	3921	3295	863	3528	3996
30–32 wk	1833	27.0	6853	966	1374	368	1501	1930
>32 wk	475	7.0	3144	328	740	211	485	1029
Location of birth								
Inborn	5433	79.9	13 384	2557	2613	703	2830	2809
Outborn	1364	20.1	18 903	3934	3241	944	3242	5248
Survival status								
Died day 1	186	2.7	1085	111	163	69	98	105
Died after day 1	640	9.4	10 900	1547	3041	831	2054	1887
Transfer	1264	18.6	12 314	2510	2250	650	2457	2846
Home	4707	69.3	16 482	3494	2998	809	3399	3701

N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network.
* All dollar figures are in constant (1998) dollars.

range, respiratory costs drop by a factor of 3 to $2250 and for the highest birth weight range, 1251 to 1500 g, they are only $840. Pharmacy costs follow a similarly strong pattern with birth weight. For infants with birth weight between 501 and 750 g, median pharmacy costs are $5600. This compares to $4400 for infants in the next 250-g birth weight range and $2800 for those with birth weight between 1251 and 1500 g. Pharmacy costs are likely higher for lower birth weights as a result of the costs of surfactants.

Another measure of patient mix is the gestational age distribution of patients in a unit. As shown in Table 1, treatment costs vary considerably by gestational age. The patterns of treatment costs for gestational age are similar to those for birth weight. Treatment costs rise with gestational ages 24 weeks and above. For infants <24 weeks' gestational age, treatment cost per infant is the lowest, $8600, as a result of high mortality rates. For these infants, median lengths of stay are only 2 days. However, it should be noted that the treatment intensity is the highest for these infants, with a median daily cost of $1780. Overall treatment costs per infant are highest for those with gestational ages between 24 and 26 weeks, with a median value of $101 600. Both lengths of stay, 79 days, and cost per day, $1560, are high. Treatment cost per infant drops markedly, by 40%, with the next highest gestational age range, 27 to 29 weeks. Infants in that gestational age range have much lower median treatment cost per infant, $63 000. Costs drop again markedly as gestational age rises more, to $34 300 for infants with gestational age of 30 to 32 weeks and $18 700 for those with gestational age >32 weeks. Given the strong relationship between treatment cost and gestational age, the gestational age distribution of infants in a given unit will influence treatment costs. To the extent that a unit disproportionately treats infants with low gestational ages (but above 24 weeks), treatment costs will be higher.

Ancillary costs also vary inversely with gestational age for infants >24 weeks' gestation. For infants 24 to 26 weeks' gestational age, ancillary costs are $33 500. For those 27 to 29 weeks, ancillary costs are only half as much, $17 160. This drops again by half for gestational ages between 30 and 32 weeks ($6850) and again by half for gestational ages >32 weeks ($3140). Respiratory therapy and pharmacy costs are particularly high for infants with gestational age between 24 and 26 weeks. The median respiratory therapy cost is $8860 and pharmacy cost is $5590. In contrast, for infants in the 27- to 29-week range, costs are much lower (with a median of $3920 for respiratory care and $3530 for pharmacy). For infants >32 weeks' gestation, respiratory costs are only $330 and pharmacy costs are $480.

Another factor that may influence costs is the mix of inborn and outborn infants, although the relation is unclear. On the one hand, infants who are outborn may spend somewhat less time in the unit than those who were inborn, but they may be more severely ill and thus more expensive to treat. The data in Table 1 show that for the hospitals in this study, the latter effect dominates the former. Although lengths of stay are lower for outborn infants (43 vs 48 days), treatment intensity is higher. Median costs per day for an outborn infant are $1500 compared with $1200 for inborn infants. The higher treatment intensity offsets the lower length of stay to yield a higher treatment cost per infant for outborn infants ($56 200) versus inborn infants ($52 700). Similarly, infants who are transferred out of a unit should have different treatment costs than those who are not transferred. Table 1 shows that infants who are transferred out have substantially lower lengths of stay, 29 days, and correspondingly lower treatment cost per infant, $41 800. Thus, the mix of inborn and outborn infants and those transferred out of the unit should be taken into consideration when comparing economic performance across units.

In summary, the distributions of birth weight and

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gestational age and mix of inborn and outborn infants should be taken into consideration when making cost comparisons across units.

ROLE OF MORTALITY

Very low birth weight infants have high mortality rates. In this sample of infants, 12% died during their initial hospitalization. Very low birth weight infants die predominantly in the first days of life. Therefore, those who do not survive their initial hospitalization have much shorter lengths of stay on average than those who do survive. This translates into lower treatment costs. Thus, the mortality status of infants in a unit will influence overall observed treatment costs per infant at the unit level.

Table 1 provides some insights into this relationship. Three percent of infants with birth weight <1500 g died during their first day of life. Treatment intensity was high for these infants, a median of $2000 for the 1-day hospital stay. Another 9% of infants died after the first day of life. The median length of stay for these infants was only 7 days. Although the cost of the hospitalization was relatively low, $18 000, treatment intensity was very high, with a median value of $2600 per day. This is more than twice as high as the daily cost for infants who lived and were discharged from the hospital ($1100). Because the median length of stay is higher for infants who are discharged from the hospital (57 days), overall treatment costs per infant are higher ($63 800) for infants who live than for those who die.

Table 3 provides additional insights into the role of mortality on treatment costs by considering how costs differ by survival status within birth weight and gestational age ranges. From Table 3, it is evident that there are enormous differences in the costs of survivors and nonsurvivors for infants with the lowest birth weights and gestational ages. For infants with birth weight <500 g, those who survived had costs per infant of $147 660. As shown in Table 4, respiratory and pharmacy costs were particularly high for these infants, with median values of $16 250 and $8980, respectively. Infants who died after the first day of life had median treatment costs of $12 970. Cost per infant for survivors in the 501- to 750-g range were $125 900, compared with $19 000 for those who survived the first day of life. The cost per survivor drops to $83 500 for infants in the 751- to 1000-g range and $51 300 for those in the 1001- to 1250-g range, and $31 900 for those in the highest range (1251–1500 g). The cost per infant who died after the first day of life is roughly comparable across all birth weight ranges. Therefore, units that have better survival rates will have higher treatment costs, particularly if they are disproportionately successful at treating infants with the lowest birth weights.

The same pattern of costs for survivors is evident within gestational age categories. Infants with gestational age <24 weeks and survived had median treatment costs of $180 000. For infants who survive, respiratory therapy and pharmacy costs are particularly high, $17 700 and $10 100, respectively (as shown in Table 4). Infants with a gestational age of <24 weeks and die after the first day of life have overall treatment costs of only $9400. Median treatment costs for infants who survive drop sharply with gestational age. For infants in the 24- to 26-week range, treatment cost per infant is $117 400. This compares to $65 100 for infants in the 27- to 29-week range and $34 600 for those with gestational age between 30 and 32 weeks. Infants with gestational age >32 weeks have median treatment costs of only $19 400. Those who are between 24 and 32 weeks' gestation and die after the first day of life have median treatment costs between $20 400 and $25 400. This drops to $7100 for those with >32 weeks' gestation. Thus, unlike birth weight, as gestational age rises, the cost difference between survivors and nonsurvivors gets smaller. This suggests that units with the highest survival rates among infants of the lowest gestational ages will have the highest costs. Improved mortality performance at higher gestational ages will have less of an impact on overall unit costs.

These results suggest that the mortality status of infants, particularly among the smallest infants, will influence overall observed treatment costs per infant at the unit level. From a quality improvement perspective, these results suggest that if quality improvement results in lower mortality rates for the smallest and least mature infants, then treatment costs at the unit level may rise. However, quality improvement also has other economic benefits. To the extent that improvements in patient quality of care increase the efficiency of care, treatment costs will go down. For instance, in a collaborative quality improvement in neonatology, it was demonstrated that overall treatment costs decreased as a result of the quality improvement initiative.[2]

ROLE OF LEVEL OF CARE

NICUs also vary in the level of care provided. This influences observed treatment costs per infant at the unit level. Table 5 presents information on median treatment costs for infants by level of care. Among the 29 hospitals, there were 13 level C units, 15 level B units, and 1 level A unit. Units with levels A and B are combined in Table 5. Level of care is ascertained yearly by the Vermont Oxford Network from its members in an annual survey. Level of care is self-reported according to the following definitions. Level A units are defined to be those with restrictions on the capability to provide assisted ventilation and that perform only minor surgery. Level B units, in contrast, perform all major surgery for newborns except cardiac surgery requiring bypass. Level C units are capable of providing cardiac surgery requiring bypass for newborns.

As shown in Table 5, treatment costs are higher for level C units than lower level units. Median treatment cost per infant for infants in level C units was $59 100 compared with $47 000 for infants in level A/B units; this represents a 20% difference. The cost differences between unit types are largely driven by differences in the intensity of care. Lengths of stay are generally similar between unit types, with a median of 48 days in level C units and 46 days in lower level units. However, the median cost per day is higher in level C units, a median of $1350 compared

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TABLE 3. Median Treatment Costs for Very Low Birth Weight Infants by Survival Status (1997-1998)*

Category	*N*	%	Total Cost	Accommodation Cost	Ancillary Cost	LOS	Cost per Day
Overall	6797		53 316	37 723	14 328	47	1249
Survival status							
Died day 1	186	2.7	1983	850	1085	1	1910
Died after day 1	640	9.4	18 041	6515	10 900	7	2619
Transfer (survived)	1264	18.6	41 830	28 103	12 314	29	1497
Home (survived)	4707	69.3	63 789	45 226	16 482	57	1140
Birth weight							
<500 g							
Died day 1	72	43.4	448	363	24	1	448
Died after day 1	38	22.9	12 966	3268	9667	4	2809
Survived	56	33.7	147 656	83 962	55 110	104	1392
501–750 g							
Died day 1	68	5.2	2423	968	1452	1	2423
Died after day 1	320	24.7	18 970	6064	11 448	6	2652
Survived	910	70.1	125 914	82 452	43 787	92	1423
751–1000 g							
Died day 1	22	1.3	2209	927	1247	1	2209
Died after day 1	170	10.2	20 763	7920	11425	9	2485
Survived	1470	88.4	83 493	56 878	25 303	68	1278
1001–1250 g							
Died day 1	14	0.8	2905	1005	1904	1	2905
Died after day 1	65	3.6	16 475	6316	9038	9	2187
Survived	1709	95.6	51 275	37 228	12 715	48	1136
1251–1500 g							
Died day 1	10	0.5	2410	1035	1208	1	2410
Died after day 1	47	2.5	15 164	5276	8830	5	2860
Survived	1826	97.0	31 876	24 679	5995	32	1035
Gestational age							
<24 wk							
Died day 1	93	37.3	786	636	51	1	786
Died after day 1	78	31.3	9398	2995	6949	3	3092
Survived	78	31.3	179 986	110 263	64 293	111	1586
24–26 wk							
Died day 1	62	3.6	2471	899	1480	1	2471
Died after day 1	353	20.3	20 367	7154	11 800	8	2598
Survived	1324	76.1	117 412	76 837	39 130	87	1408
27–29 wk							
Died day 1	21	0.8	2119	1053	1099	1	2119
Died after day 1	145	5.8	19 019	6978	10 427	8	2451
Survived	2335	93.4	65 120	45 309	17 629	56	1208
30–32 wk							
Died day 1	5	0.3	3335	1148	1571	1	3335
Died after day 1	50	2.7	25 407	9249	12 835	10	2636
Survived	1778	97.0	34 564	26 878	6834	36	1032
>32 wk							
Died day 1	5	1.1	3017	575	2060	1	3017
Died after day 1	14	2.9	7081	2656	3609	3	2500
Survived	456	96.0	19 388	16 484	3125	23	944
Location of birth							
Inborn							
Died day 1	145	2.7	1476	786	548	1	1401
Died after day 1	467	8.6	17 534	6280	10427	7	2469
Survived	4821	88.7	57 561	41 362	14 449	52	1156
Outborn							
Died day 1	41	3.0	3097	1113	1912	1	3097
Died after day 1	173	12.7	19 635	6803	11 866	6	3000
Survived	1150	84.3	64 370	42 030	20 941	50	1370

N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network.
* All dollar figures are in constant (1998) dollars.

with $1160. Accommodation costs are higher in level C units, with a median value of $42 000, compared with $33 000 in lower level units. This represents a difference of 20% and is largely driven by differences in the cost per day, as lengths of stay do not differ widely between unit types. Ancillary costs are higher at level C units by approximately 20% as well ($15 800 compared with $12 700). As shown in Table 6, pharmacy and laboratory costs differ widely between unit types. For instance, median laboratory costs for level C units are $3200 compared with $2250 for level A/B units. Pharmacy costs are $3740 compared with $2130. In contrast, differences in the cost of respiratory care are not as large, with a median value of $2840 for level C units and $2630 for lower level units.

It is worth noting that the birth weight and gestational age distributions of infants treated in the level C and level A/B units are generally similar, as are the mortality distributions. Although we have seen above that birth weight, gestational age, and survival influence treatment costs, differences in patient mix

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TABLE 4. Median Ancillary Costs for Very Low Birth Weight Infants by Survival Status (1997-1998)*

Category	*N*	%	Total Ancillary	Respiratory	Laboratory	Radiology	Pharmacy	Other Ancillary
Overall	6797		14 328	2752	2743	752	2892	3215
Survival status								
Died day 1	186	2.7	1085	111	163	69	98	105
Died after day 1	640	9.4	10 900	1547	3041	831	2054	1887
Transfer								
Transfer (survived)	1264	18.6	12 314	2510	2250	650	2457	2846
Home (survived)	4707	69.3	16 482	3494	2998	809	3399	3701
Birth weight								
<500 g								
Died day 1	72	43.4	24	0	0	0	0	0
Died after day 1	38	22.9	9667	1144	2346	552	1903	1175
Survived	56	33.7	55 110	16 247	10 358	3429	8982	9760
501–750 g								
Died day 1	68	5.2	1452	205	304	129	351	287
Died after day 1	320	24.7	11 448	1707	3319	840	2075	1732
Survived	910	70.1	43 787	12 205	8865	2194	7501	9248
751–1000 g								
Died day 1	22	1.3	1247	211	211	115	209	237
Died after day 1	170	10.2	11 425	2380	3198	938	2232	2051
Survived	1470	88.4	25 303	6708	4861	1278	4838	5348
1001–1250 g								
Died day 1	14	0.8	1904	219	410	222	247	422
Died after day 1	65	3.6	9038	1079	2495	644	1826	2033
Survived	1709	95.6	12 715	2336	2351	633	2817	2955
1251–1500 g								
Died day 1	10	0.5	1208	169	356	89	357	17
Died after day 1	47	2.5	8830	960	2460	673	1802	1849
Survived	1826	97.0	5995	845	1182	340	1320	1643
Gestational age								
<24 wk								
Died day 1	93	37.3	51	0	0	0	0	13
Died after day 1	78	31.3	6949	1044	2472	673	1620	1326
Survived	78	31.3	64 293	17 696	14 380	3311	10 100	10 818
24–26 wk								
Died day 1	62	3.6	1480	261	299	131	341	311
Died after day 1	353	20.3	11 800	2021	3217	857	2142	1818
Survived	1324	76.1	39 130	10 972	7594	2001	7011	8217
27–29 wk								
Died day 1	21	0.8	1099	154	225	106	160	176
Died after day 1	145	5.8	10 427	1363	3132	810	2118	2062
Survived	2335	93.4	17 629	4090	3344	882	3671	4153
30–32 wk								
Died day 1	5	0.3	1571	254	528	355	341	0
Died after day 1	50	2.7	12 835	1828	3451	999	2126	2703
Survived	1778	97.0	6834	959	1347	360	1490	1915
>32 wk								
Died day 1	5	1.1	2060	55	416	236	40	918
Died after day 1	14	2.9	3609	486	569	280	746	832
Survived	456	96.0	3125	331	753	205	485	1029
Location of birth								
Inborn								
Died day 1	145	2.7	548	32	78	46	25	59
Died after day 1	467	8.6	10 427	1466	3021	810	2083	1665
Survived	4821	88.7	14 449	2878	2715	727	3055	3105
Outborn								
Died day 1	41	3.0	1912	197	438	190	275	499
Died after day 1	173	12.7	11 866	1768	3340	951	1742	2740
Survived	1150	84.3	20 941	4722	3418	1022	3622	5711

N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network.
* All dollar figures are in constant (1998) dollars.

in these dimensions are not driving observed differences in treatment costs. Infants in level C units are somewhat more likely to be outborn (22% vs 18%) and to be transferred out of the unit (21% vs 16%), which may drive some of the observed differences but not all. Thus, differences between unit types are likely to reflect unmeasured factors, such as the severity of patient mix and costs associated with specialized types of surgery such as for cardiac care. Thus, in comparing economic performance across units, it is also important to consider the type of unit in addition to differences in birth weight, gestational age, and mortality differences.

CONCLUSIONS

Neonatal intensive care costs for infants with very low birth weight are high. On average, median treatment costs per infant are $53 300 in 1998 constant dollars. When comparing economic performance across units, it is important to take into consideration

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TABLE 5. Median Treatment Costs for Very Low Birth Weight Infants by Level of Care (1997-1998)*

Category	*N*	%	Total Cost	Accommodation Cost	Ancillary Cost	LOS	Cost Per Day
Overall	6797		53 316	37 723	14 328	47	1249
NICU type							
Type A/B unit	3289	48.4	47 038	33 021	12 676	46	1162
Type C unit	3508	51.6	59 130	41 991	15 803	48	1352
Among type A/B units							
Birth weight							
<500 g	93	2.8	15 559	4175	12271	4	1401
501–750 g	642	19.5	95 964	52 895	34 006	81	1510
751–1000 g	785	23.9	71 915	46 626	21 564	64	1269
1001–1250 g	862	26.2	42 334	30 439	10 387	46	1053
1251–1500 g	907	27.6	28 932	22 367	5068	32	977
Gestational age							
<24 wk	132	4.0	7320	1582	5079	2	1764
24–26 wk	849	25.8	94 797	55 092	32 985	78	1480
27–29 wk	1164	35.4	58 293	39 087	16 220	55	1162
30–32 wk	898	27.3	31 534	24 242	6022	36	958
>32 wk	246	7.5	16 956	13 854	2644	23	884
Location of birth							
Inborn	2699	82.1	46 336	32 640	12 173	47	1141
Outborn	590	17.9	49 085	33 914	15 412	44	1290
Survival status							
Died day 1	85	2.6	1866	869	1030	1	1758
Died after day 1	314	9.5	16 437	5501	10 672	7	2471
Transfer	533	16.2	39 701	27 524	11 246	30	1354
Home	2357	71.7	55 387	38 718	14 025	54	1077
Among type C units							
Birth weight							
<500 g	73	2.1	3170	993	2483	1	1085
501–750 g	656	18.7	108 374	73 648	34 887	80	1810
751–1000 g	877	25.0	84 767	59 956	25 607	67	1437
1001–1250 g	926	26.4	56 588	40 898	14 138	48	1258
1251–1500 g	976	27.8	33 412	25 830	7000	31	1113
Gestational age							
<24 wk	117	3.3	19 196	6164	8414	3	1796
24–26 wk	890	25.4	107 045	72 561	34 011	80	1723
27–29 wk	1337	38.1	66 697	46 797	18 117	55	1330
30–32 wk	935	26.7	37 523	28 587	7793	35	1134
>32 wk	229	6.5	21 777	18 017	3756	21	1022
Location of birth							
Inborn	2734	77.9	58 834	42 985	14 504	49	1280
Outborn	774	22.1	62 024	37 534	21 931	42	1716
Survival status							
Died day 1	101	2.9	2053	822	1098	1	2004
Died after day 1	326	9.3	19 546	7318	10 943	7	2748
Transfer	731	20.8	43 757	28 752	12 840	28	1670
Home	2350	67.0	71 681	51 286	18 667	60	1218

N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network; number of level A/B NICUs = 16; number of level C NICUs = 13.
* All dollar figures are in constant (1998) dollars.

factors that influence treatment costs. These include birth weight, gestational age, and survival. Treatment costs are inversely related to birth weight for infants with birth weight >500 g. Similarly, treatment costs fall with gestational age for infants with gestational age >24 weeks. Thus, the birth weight and gestational age distributions of patients in a NICU will affect observed treatment costs. To the extent that these factors change over time, overall treatment costs per infant will also change. In some cases, an unusual spike in the low birth weight or earlier gestational age distribution in a given year, particularly for a small unit, could generate unusually high costs for that year. In interpreting time trends, it is therefore important also to consider the trend in the composition of the patients in the unit.

Treatment costs also depend on survival. Because most very low birth weight infants die in the first days of life, overall treatment costs per infant are lower for infants who die than for those who survive. Thus, units with better survival will also have higher treatment costs. Quality improvement efforts that improve survival may therefore increase costs, particularly if survival is improved for infants with birth weight <750 g and gestational age <24 weeks. The difference in median treatment cost per infant for a 501- to 750-g infant who survives versus one who dies after the first day of life is $107 000. The difference in median treatment cost per infant for a infant who has a gestational age between 24 and 26 weeks and survives compared with dying after the first day of life is $170 600. Quality improvement efforts, however, may also increase the efficiency of care, which may counterbalance any increases in cost associated with improved survival. Recent evidence from a collaborative quality improvement in neonatology demonstrated that this is possible.[2]

In addition, level C units have costs that are higher

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TABLE 6. Median Ancillary Costs for Very Low Birth Weight Infants by Level of Care (1997-1998)*

Category	*N*	%	Total Ancillary	Respiratory	Laboratory	Radiology	Pharmacy	Other Ancillary
Overall	6797		14 328	2752	2743	752	2892	3215
NICU type								
Type A/B unit	3289	48.4	12 676	2626	2249	667	2133	3194
Type C unit	3508	51.6	15 803	2835	3212	841	3736	3242
Among type A/B units								
Birth weight								
<500 g	93	2.8	12 271	1157	2389	837	1670	1386
501–750 g	642	19.5	34 006	10 064	6068	1648	4732	7172
751–1000 g	785	23.9	21 564	6250	3841	1095	3356	4852
1001–1250 g	862	26.2	10 387	2031	1851	545	1898	2996
1251–1500 g	907	27.6	5068	821	1069	335	995	1524
Gestational age								
<24 wk	132	4.0	5079	646	1071	382	1143	736
24–26 wk	849	25.8	32 985	9827	5836	1565	4634	6804
27–29 wk	1164	35.4	16 220	4243	2962	779	2667	4145
30–32 wk	898	27.3	6022	924	1225	364	1085	1802
>32 wk	246	7.5	2644	310	650	204	337	929
Location of birth								
Inborn	2699	82.1	12 173	2513	2228	635	2043	2855
Outborn	590	17.9	15 412	3140	2429	804	2528	4499
Survival status								
Died day 1	85	2.6	1030	119	122	69	59	93
Died after day 1	314	9.5	10 672	1526	2887	746	1869	1944
Transfer	533	16.2	11 246	2846	1921	587	1925	2892
Home	2357	71.7	14 025	3205	2443	708	2416	3541
Among type C units								
Birth weight								
<500 g	73	2.1	2483	219	438	241	604	292
501–750 g	656	18.7	34 887	8655	7367	1936	7396	6137
751–1000 g	877	25.0	25 607	6058	5141	1363	5788	4937
1001–1250 g	926	26.4	14 138	2507	2711	705	3737	2841
1251–1500 g	976	27.8	7000	848	1334	351	1717	1731
Gestational age								
<24 wk	117	3.3	8414	1201	1927	725	1538	1584
24–26 wk	890	25.4	34 011	8277	7136	1908	7588	5878
27–29 wk	1337	38.1	18 117	3661	3535	937	4394	3861
30–32 wk	935	26.7	7793	1003	1523	378	2012	2051
>32 wk	229	6.5	3756	334	851	236	775	1111
Location of birth								
Inborn	2734	77.9	14 504	2580	2985	772	3666	2781
Outborn	774	22.1	21 931	4261	4055	1091	3957	5725
Survival status								
Died day 1	101	2.9	1098	99	239	91	139	154
Died after day 1	326	9.3	10 943	1547	3198	897	2176	1710
Transfer	731	20.8	12 840	2329	2520	714	2784	2830
Home	2350	67.0	18 667	3646	3622	949	4726	3953

N = 29 hospitals in the NIC/Q 2000 project of the Vermont Oxford Network; number of level A/B NICUs = 16; number of level C NICUs = 13.
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(by approximately 20%) than level A/B units despite having similar distributions of birth weight, gestational age, and survival. Costs are higher as a result of the intensity of care provided, not lengths of stay. Both accommodation and ancillary costs are higher for these units. Differences between unit types likely reflect unmeasured differences in severity and in the costs associated with specialized types of surgery, such as those for cardiac care.

Information on treatment costs provides a tool to ascertain the economic performance of NICUs and to determine the effects of quality improvement efforts. However, it is important that measures of cost be created in a uniform manner across institutions so that these costs are comparable. In addition, when comparing costs across units, it is vital to take into consideration factors that influence costs, including the distributions of birth weight, gestational age, survival, and the level of care of the unit.

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Using Economic Information in a Quality Improvement Collaborative

Jeannette Rogowski

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