Neonatal Mortality Clusters: A New Tool For Classifying Neonatal Outcomes

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Abstract:* *Background: **A method for assessing general hospital neonatal care performance is needed that is simple, is easy to use, and requires minimal data.**

Methods: **All neonatal deaths in Washington State obstetric hospitals from 1980 to 1983 were assigned to 10 mutually exclusive neonatal mortality clusters, a new classification method derived from information available on the death certificate.**

Results: **More than one-third (35.3 percent) of all neonatal deaths fell within one of the seven clusters considered to represent potentially preventable causes of death. The rate of possibly preventable deaths was much higher in level III hospitals than in level II or level I hospitals, a finding similar to that observed in other states using different analytic approaches.**

Conclusions: **Neonatal mortality clusters offer a less complex method of classifying neonatal deaths and assessing hospital performance than other currently used techniques. (J Am Board Fam Pract 1991; 4:299-306)**

Regionalization of perinatal care has been adopted as a major strategy in the attempt to improve perinatal survival.[1,2] A central objective of regionalization is to reduce regional disparities in perinatal outcome by encouraging early detection and appropriate transfer of women with high-risk pregnancies to appropriate referral centers.[3-6] A key element of a regionalized system is the classification of obstetric facilities according to their ability to handle maternal and neonatal complications.

Even within the context of a regionalized perinatal care system, similar individual hospitals differ in the success with which they manage complications arising in the perinatal period.[7] Ongoing surveillance and periodic outcome evaluations are essential tools in the constant attempt to improve the function of each hospital in the system.[8] To accomplish these objectives, outcome must be measured efficiently, accurately, and in ways easily explainable. Crude mortality rates are misleading, particularly in a regionalized system of care where hospitals with different capabilities have very different patient populations.[9] Birth-weight-specific mortality rates are a better measure of relative performance by controlling for the variable—birth weight—which has been shown to be the best single measure of perinatal risk.[10] Perinatal deaths are relatively rare, however, and thus birth-weight-specific perinatal mortality rates are of limited utility in comparing the performance of individual hospitals, particularly those with relatively few births or deaths.[8]

Two techniques have been proposed to overcome these limitations. The first—standardizing for birth weight by calculating the standardized mortality ratio (SMR) for individual hospitals—has been used quite successfully as both a surveillance and research technique[7,11-13] but has several serious limitations. The resulting statistic is biased against populations with heavier birth weights and can obscure important differences in outcome for specific birth-weight groups within hospitals.[14] Calculating SMRs also requires linked birth and death records and considerable statistical sophistication.

Submitted, revised, 7 March 1991.

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This research was supported, in part, by grants from the Fogarty Center, National Institutes of Health; the Medical Research Council of New Zealand; the W.K. Kellogg Foundation; and the Clinical Scholars Program of the Robert Wood Johnson Foundation.

A second approach was introduced by Hein and Brown in 1981[15] as a way to evaluate the performance of individual level I, level II, and level III hospitals. Based on an intensive examination of cases of neonatal death in Iowa during a 2-year period, Hein and Brown's technique allowed them to assign a cause of death to most of the cases observed during the study period and to identify those deaths that were possibly preventable. This technique focuses attention on those obstetric and neonatal units within the regionalized perinatal system where improved outcomes might be achieved. That their technique requires intimate knowledge of all the hospitals in the system and meticulous case-by-case review is a disadvantage.

The study reported here presents a method of neonatal mortality review using routinely collected data to identify potentially preventable neonatal deaths. Our purpose is to present a surveillance mechanism that has less extensive data requirements than the calculation of birthweight-specific mortality rates and standardized mortality ratios. In this investigation, we report the results of using the cause of death as recorded on the death certificate—maintained as part of the vital statistics system—to assess neonatal outcome within Washington State during a 4-year period.

Methods

From 1980 to 1983, 90 hospitals in Washington State routinely offered obstetric services. Ninety-six percent of all births in the state occurred in these hospitals. The remainder occurred in freestanding birthing centers, physicians' offices, at hospitals that did not routinely provide obstetric care, on transit to the hospital, or at home. Births in these nonhospital locations were excluded from the analysis. After the exclusions, there were 264,618 births and 1571 neonatal deaths—deaths of live-born infants aged between 0 and 27 days—recorded for the 4-year study period.

Hospital Characteristics

Using telephone interviews with hospital staff, we assigned all 90 hospitals to a level of care according to guidelines published by the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists.[16] All six level III facilities currently recognized as such by the state were assigned level III status and conformed to the published criteria. The 11 hospitals classified by our telephone survey as level II offered varying levels of respiratory support, but all had in-house anesthetists or anesthesiologists for resuscitation and stabilization, and all had the capability to treat sepsis, perform exchange transfusion, and manage intra-arterial catheters. The level I hospitals were those offering routine obstetric care that did not meet the criteria for level II or level III designation.

Data from this study came from the Washington State linked birth and infant death records.[17,18] All infant deaths (≤ 1 year of age) were matched with the appropriate birth certificate. Information abstracted from the record in each case included the birth weight of the infant, the hospital of birth, the age of the infant at the time of death, and the main cause of death as recorded using the *International Classification of Diseases–Ninth Revision* (ICD-9)[19] classification.

Each main cause of death listed in this data set was assigned to one broad diagnostic cluster; the diagnostic rubrics included in each cluster are shown in the Appendix. Aggregating similar diagnoses into larger categories reduces the effect of idiosyncratic coding behavior of individual clinicians and makes it possible to deal in a clinically meaningful way with the hundreds of diagnostic rubrics employed.[20] Each diagnostic cluster was further characterized as representing a "possibly preventable" or "probably nonpreventable" cause of death.

All deaths of infants weighing less than 750 g at birth were considered to be probably nonpreventable and were assigned to a diagnostic cluster named "extreme immaturity" regardless of the ICD-9 code given as the cause of death. The 58 infants with missing birth weights were assigned to clusters according to the main cause of death. All deaths attributable to severe malformations in infants weighing 750 g or more at birth were clustered into a second group of probably nonpreventable deaths. A handful of other codes considered probably nonpreventable were lumped together as "other."

The remainder of codes were deemed possibly preventable and grouped into six clinical categories. For example, individual codes denoting severe birth asphyxia, unspecified birth asphyxia in live-born infants, and fetal death from asphyxia or

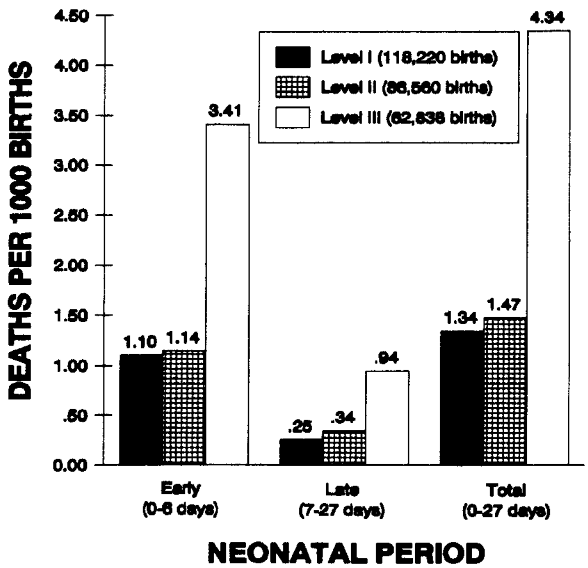

Figure 1. Rate of possibly preventable neonatal deaths for Washington State by hospital level, 1980–1983.

anoxia during labor were all combined with similar diagnoses into one category called asphyxia. Causes of death relating to birth trauma, bacterial infections, and prematurity or immaturity with birth weight greater than 750 g were grouped to form three other categories. Complications of pregnancy, such as abruptio placentae, were grouped as maternal complications. Remaining codes thought to be possibly preventable were grouped as "other."

Each diagnosis was assigned to only one diagnostic cluster. Because of the limitations inherent in using death certificate data, we were conservative in assigning any perinatal death to the possibly preventable category. The intent of the classification was to focus on those cases with a high likelihood that death could have been averted.

After all public maternity hospitals in Washington State had been aggregated according to their level of care, the number of deaths and causes of death—separated into possibly preventable and probably nonpreventable clusters—were determined for each hospital level. Each case was assigned to the hospital where the infant was born regardless of the ultimate place of death. Thus, a death that occurred in a level III hospital after a neonatal transfer would be attributed to the hospital where the birth occurred.

Results

Perinatal care in Washington State is highly regionalized; although 45 percent of all births occurred in level I hospitals, only 16 percent of the very-low-birth-weight births (1000–1499 g) and 35 percent of the low-birth-weight births (1500–2500 g) occurred in those hospitals. Infants weighing less than 1500 g accounted for only 0.16 percent of the deliveries in level I hospitals compared with 1.2 percent of all deliveries in level III

Table 1. Neonatal Deaths in Washington State, 1980–1983, by Cause and Hospital Level.

	Hospital Level Where Birth Occurred (number of cases)			
	Level I	Level II	Level III	Total
Diagnostic Cluster	No. (%)	No. (%)	No.(%)	No. (%)
Possibly preventable				
Respiratory dysfunction (including respiratory distress syndrome)	72 (15.9)	52 (13.7)	151 (20.4)	275 (17.5)
Asphyxia	20 (4.4)	20 (5.3)	24 (3.2)	64 (4.1)
Bacterial infections	13 (2.9)	13 (3.4)	25 (3.4)	51 (3.2)
Birth trauma	16 (3.5)	18 (4.7)	36 (4.9)	70 (4.5)
Selected maternal complications of pregnancy	22 (4.9)	8 (2.1)	17 (2.3)	47 (3.0)
Prematurity or immaturity (≥ 750 g)	11 (2.4)	9 (2.4)	15 (2.0)	35 (2.2)
Other	5 (1.1)	3 (0.8)	5 (0.7)	13 (0.9)
Subtotals	159 (35.2)	123 (32.4)	273 (36.9)	555 (35.3)
Probably nonpreventable				
Extreme immaturity (< 750 g)	94 (20.8)	108 (28.4)	266 (36.0)	468 (29.8)
Congenital malformations	172 (38.1)	120 (31.6)	146 (19.8)	438 (27.9)
Other	27 (6.0)	29 (7.6)	54 (7.3)	110 (7.0)
Subtotals	293 (64.8)	257 (67.6)	466 (63.1)	1,016 (64.7)
Totals	452 (100.0)	280 (100.0)	739 (100.0)	1,571 (100.0)

Table 2. Comparative Neonatal Outcomes in Hospitals with Level II and Level III Obstetric Units, Washington State, 1980–1983.

Hospital Level	Hospital Identifier	Total Live Births	Percent of Births < 1500 g	Crude Neonatal Mortality Rate (per 1000 births)	Number of Possibly Preventable Neonatal Deaths
III	1	8,339	7.79	27.22	89
III	2	10,351	1.55	7.92	24
III	3	11,109	1.72	8.91	29
III	4	9,465	1.02	5.81	27
III	5	11,005	1.72	10.00	34
III	6	12,569	2.20	13.21	70
II	7	8,078	0.28	2.97	6
II	8	2,740	0.51	3.65	4
II	9	9,023	0.34	3.21	13
II	10	5,990	0.30	3.34	10
II	11	9,159	0.48	4.15	12
II	12	13,630	0.32	4.26	13
II	13	6,843	1.23	8.18	25
II	14	8,669	0.35	4.50	8
II	15	5,919	0.52	5.07	14
II	16	7,161	0.42	5.87	7
II	17	6,348	0.30	5.36	11

hospitals, with level II hospitals occupying an intermediate position.

Table 1 presents the distribution of neonatal deaths that occurred in infants born in all level I, level II, and level III obstetric hospitals in Washington State. The larger two categories were the probably nonpreventable diagnostic clusters extreme immaturity and congenital malformations, accounting for 29.8 and 27.9 percent of all neonatal deaths, respectively. The largest category of possibly preventable death was respiratory dysfunction (including respiratory distress syndrome), which accounted for 17.5 percent of all neonatal deaths and one-half of those classified as possibly preventable. Three additional diagnostic clusters in the category of possibly preventable death each accounted for at least 3 percent of neonatal deaths: asphyxia, birth trauma, and bacterial infections. Together with respiratory dysfunction, these four diagnostic clusters represented 29.3 percent of all neonatal deaths and 82.9 percent of those classified as possibly preventable.

Of all neonatal deaths, 35.3 percent were classified as possibly preventable by this technique, 35.2 percent in level I hospitals, 32.4 percent in level II hospitals, and 36.9 percent in level III hospitals, differences that were not statistically significant. Although the proportion of possibly preventable neonatal deaths was similar across hospital level, the rates of possibly preventable deaths per 1000 births showed more pronounced differences. As seen in Figure 1, level I and level II hospitals had approximately the same rate of possibly preventable neonatal deaths: 1.34 and 1.47 per 1000 births, while the rate for level III hospitals was approximately three times as high at 4.34 per 1000 births, a highly significant difference ($P < 0.0001$). Similar differences exist in both the early and late neonatal period as well. This difference in the rate of possibly preventable deaths parallels the fact that level III hospitals had a disproportionately large number of neonatal deaths in general: 47 percent of all births that resulted in a neonatal death in Washington State occurred in six level III hospitals, although only 24 percent of the births took place in these hospitals.

The identification of the location of possibly preventable deaths facilitates study of the comparative performance of individual hospitals, as shown in Tables 2 and 3. Among the level III hospitals, hospital 1 differed from the rest of the cohort. Almost 8 percent of all infants born in this hospital were under 1500 g; the next highest proportion of very-low-birth-weight infants in an individual hospital was less than one-third that proportion. Fourteen percent of all births that ended in a neonatal death—and 16 percent of deaths categorized as possibly preventable—

Table 3. Comparative Neonatal Outcomes in Selected Hospitals with Level I Obstetric Units, Washington State, 1980–1983.

Hospital Level	Hospital Identifier	Total Live Births	Percent of Births < 1500 g	Crude Neonatal Mortality Rate (per 1000 births)	Number of Possibly Preventable Neonatal Deaths
Example A —hospitals with no neonatal deaths					
I	18	12	0	0	0
I	19	22	0	0	0
I	20	238	0	0	0
I	21	1,060	0.38	0	0
I	22	543	0.55	0	0
Example B — hospitals with neonatal deaths but no possibly preventable deaths					
I	28	526	0.18	5.70	0
I	29	329	0	6.08	0
Example C — hospitals with possibly preventable deaths					
I	23	2,910	0.41	1.37	2
I	25	2,858	0.31	3.15	3
I	26	351	0.57	2.85	1
I	31	129	0.78	7.75	1
I	30	186	0.54	10.75	1

occurred in this one facility. By contrast, hospital 6 had a large number of possibly preventable deaths—12.6 percent of all those in the state during the study period—but a much smaller proportion of very-low-birth-weight infants. This finding suggests that additional attention to the process of care in this latter institution may be worthwhile.

The same sort of scrutiny can be used in the level II cluster of hospitals. The data illustrate that hospital 13 differed from its peers by having a higher proportion of very-low-birth-weight infants and a relatively large number of possibly preventable deaths. With the exception of hospital 13, no other level II hospital had 15 or more possibly preventable neonatal deaths during the 4-year study period. By contrast, hospital 7 had a pattern that made it more compatible with a large level I hospital, with very few low-birth-weight infants and very few possibly preventable deaths.

Because there were 73 level I hospitals in the state, only a subset was included in Table 3 to illustrate the utility of this technique. Example A shows 5 of the 14 hospitals that had no births ending in neonatal death during the 4-year study period. The first three hospitals in this group had very few deliveries and no births of infants less than 1500 g. The last two hospitals in this group had higher volumes of deliveries and a few very-low-birth-weight infants but no neonatal mortality.

By contrast, example B shows two hospitals that did experience neonatal deaths but had no deaths categorized as possibly preventable. Although the crude neonatal mortality rates were relatively high for these level I hospitals, neither of these institutions had large numbers of low-birth-weight infants, and in both cases the deaths were due to causes deemed to be probably nonpreventable.

Example C shows five hospitals with at least one death categorized as possibly preventable. Given limited resources, this finding suggests that further scrutiny of these cases is indicated.

Discussion

Regionalization of perinatal care is an effective way to rationalize the organization of perinatal services and improve pregnancy outcomes for populations served by a collection of perinatal facilities with different levels of capability. A critical element of such a system is the ability to evaluate the performance of individual hospitals and groups of similar hospitals within the context of a regionalized system. The purpose of this report is to present a new tool for the analysis of neonatal outcomes that uses the information collected on neonatal death certificates to categorize individual neonatal deaths as either possibly preventable or probably nonpreventable and to cluster together deaths with similar causes.

The main advantage of this technique is simplicity. The only data requirements are the birth weight and cause of death of infants born in identified hospitals during the neonatal period, information that is generally available as a component of the vital statistics system. Determination of the number and location of possibly preventable perinatal deaths does not require linking birth and death files or manipulating the entire computerized birth file for states or other geopolitical entities. Furthermore, unlike such measures as the standardized mortality ratio, no statistical sophistication is required in the calculation or interpretation, and the results are expressed in commonly used clinical terms.

In this paper, we determined the number and location of possibly preventable neonatal deaths in Washington State obstetric hospitals during the years 1980-1983. We found that approximately one-half of all possibly preventable neonatal deaths occurred in the state's six level III obstetric facilities. This finding may reflect that in Washington's highly regionalized perinatal care system, a disproportionately large number of high-risk births occur in level III hospitals. One-half of all the neonatal deaths in the state occurred in infants weighing between 750 and 2500 g at birth, and 55 percent of these children were born in level III hospitals. Transfer of women with high-risk pregnancies is effectively concentrating those babies in need of sophisticated neonatal intensive care in those facilities capable of offering it.

The use of neonatal mortality clusters complements standardized mortality ratios and birth-weight-specific neonatal mortality rates in the evaluation of the performance of individual hospitals. Particularly in reviewing the performance of small obstetric facilities, the presence of one possibly preventable neonatal death in a baby born in that facility provides an opportunity for more intensive neonatal mortality review, no matter what the standardized mortality ratio or the birth-weight-specific mortality rates. From a system standpoint, it is reassuring that there are no small hospitals in Washington State with large numbers of possibly preventable deaths. Further significant improvements in outcome will require either the prevention of the conditions that lead to low-birth-weight infants or qualitative improvements in the salvage of very-low-birth-weight infants.

Correlations with Other Studies

The results of this study are in harmony with work done by Bowes in Colorado and Hein and Lathrop in Iowa. Bowes and colleagues[13] used the linked birth and death certificates in Colorado to calculate standardized mortality ratios so they could assess the quality of perinatal care in Colorado. They used the cause of death to create a category termed "probably untreatable" and then adjusted the standardized mortality rates to account for the proportion of deaths attributed to untreatable disorders.

The major difference between the approach of Bowes, et al. and that reported in this study was in the way in which very-low-birth-weight infants were handled. Bowes, et al. chose to consider infants of all weights as possibly treatable, whereas we conservatively assigned all infants with birth weights less than 750 g to the probably untreatable group. If one considers the 468 infants in our sample that weighed less than 750 g to be potentially treatable, 35 percent of the Washington State births would be classified in the nonpreventable category, a rate very similar to the 31 percent so classified by Bowes, et al. The major disadvantage of the method adopted by Bowes, et al. is that it is a hybrid that requires the investigator to compute standardized mortality ratios and subsequently correct this figure on the basis of presumed untreatability. It would seem to be both simpler and more informative to use the two methods as separate but complementary approaches.

The results of our study were remarkably similar to those presented by Hein and Lathrop[21] in their study of neonatal mortality in Iowa. Using the method of intensive clinicopathological review of neonatal deaths, Hein and Lathrop compared the outcomes in Iowa for the years 1982 and 1983 with the results they obtained in an earlier review of neonatal deaths in 1978 and 1979. They found that the greatest reduction in preventable neonatal mortality had occurred in level I hospitals, and the largest reservoir of potentially preventable neonatal deaths was in the level II and level III centers. This result was virtually identical to that obtained in our study in Washington State, where 71.4 percent of the deaths identified as possibly preventable occurred to infants born in level II and level III hospitals. Hein and Lathrop argued that the Iowa data were consistent with a maturing regionalized system of care in which physicians in level I centers were screening and referring patients at risk.

The technique of using neonatal mortality clusters to identify potentially preventable neonatal deaths is a derivative of Hein and Lathrop's pioneering work in the development of neonatal mortality review. The advantage of our technique is that it is much less labor intensive than Hein and Lathrop's approach, which required case-by-case review in the hospitals in which the neonatal deaths occurred. The major disadvantage of our method is that the assignment of the cause of death was based on only a fraction of the information available in the process of detailed case review. It is reassuring to note that results obtained in Iowa and Washington through these two methods were so similar.

Limitations of the Method

Unlike the determination of birth-weight-specific perinatal mortality rates, determining cause of death requires judgment on the part of the person filling out the death certificate. It is possible that systematic bias enters into the process of assigning cause of death. For example, it is possible that clinicians in level III hospitals were more likely than those in level I hospitals to assign the main cause of death to respiratory insufficiency, particularly for cases in which there was a coincidental congenital malformation. This coding bias might help explain the finding that the rate of preventable neonatal deaths was higher in level III than in level II or level I facilities. Second, the clustering technique itself by definition blurs important distinctions in the process of aggregating diagnoses into 19 broader clinical categories. Although for the sake of consistency we assigned all births of less than 750 g and all congenital malformations to the probably nonpreventable category, an unknown proportion of deaths deemed to be possibly preventable represents cases in which no intervention would have made a difference. Only an in-depth case-by-case review would provide sufficient data for one to be confident in assigning a case to one category or another, and even then the reviewer could not be certain that any given death was truly preventable.

Finally, that a large proportion of all infants who died of a potentially preventable cause in the neonatal period were born in a level III hospital does not necessarily imply that the death could have been prevented in the level III setting. Prevention of neonatal mortality begins before conception, and the influence of prenatal care and maternal transport must be considered in trying to determine how a particular preventable neonatal death might be averted. Further research must attempt first to validate this technique of neonatal mortality review by intensive review of cases identified with this method. If the technique is both reliable and valid, it would be worthwhile to determine where in the continuum of prenatal, intrapartum, and neonatal care different interventions would have a favorable impact on outcome.

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Appendix

Neonatal Mortality Diagnostic Clusters: Creation of Possibly Preventable and Probably Nonpreventable Categories

Diagnostic Cluster	Causes of Death—ICD-9 Codes
Possibly preventable	
Respiratory dysfunction (including respiratory distress syndrome)	511.8, 512.0, 516.8, 769.0, 770.1-770.5, 770.7, 770.8
Birth trauma	767.0, 767.8, 767.9, 772.1, 772.4, 772.9, 910.8, 911.0, 913.0, 968.9
Bacterial infections	36.2, 38.0, 76.9, 320.2, 322.9, 485.0, 486.0, 770.0, 771.4, 771.8
Asphyxia	276.2, 427.5, 458.9, 768.2, 768.4, 768.5, 768.9
Prematurity or immaturity (⩾ 750 g)	764.0, 765.0, 765.1
Selected maternal complications of pregnancy	760.0, 761.0, 761.1, 761.3, 761.5, 761.7, 762.0, 762.1, 762.3, 762.4, 762.5, 763.8
Other	276.5, 276.7, 560.2, 764.9, 766.2, 771.7, 773.0, 773.2, 775.0, 775.7, 779.9, 967.9
Probably nonpreventable	
Congenital malformations and defects	228.0, 259.4, 359.2, 416.0, 424.1, 553.1, 553.3, 740.0, 741.0, 741.9-742.4, 742.9, 745.0-745.6, 745.8, 746.0-746.5, 746.7-747.4, 747.6, 747.9, 748.3, 748.5, 748.6, 748.9, 750.3, 751.1, 751.3, 751.5, 753.0-753.2, 753.5, 753.9, 755.8, 756.0, 756.3, 756.5-756.8, 758.0-758.2, 758.5, 758.6, 758.9, 759.0, 759.4, 759.7-759.9, 776.5
Extreme immaturity (< 750 g) Classified by weight	
Other	54.9, 74.2, 79.1, 348.5, 430.0, 487.1, 511.9, 557.0, 586.0, 760.5, 761.6, 771.1, 771.2, 773.3, 776.2, 776.3, 777.5, 777.6, 778.0, 779.8, 798.0