Reducing Postneonatal Mortality in West Virginia: A Statewide Intervention Program Targeting Risk Identified at and after Birth

David Z. Myerberg, MD, Robert G. Carpenter, PhD, Cynthia F. Myerberg, RN, Christine M. Britton, Charles W. Bailey, and Barry E. Fink

Abstract

Objectives. Excessive postneonatal mortality in West Virginia has been associated with inadequate health care. This paper describes two interventions aimed at those infants at greatest risk of dying.

Methods. Two systems of risk-related intervention were simultaneously introduced and funded statewide from 1985 through 1987. Risk status was determined by a multifactorial score at birth or clinical risk factors later. At-risk infants were linked with physicians who provided specified care plans. All infants were followed for 1 year for mortality.

Results. Of 4570 infants with a high Sheffield Birth Score, 45%, together with 1003 infants with clinical risk factors, received specified care plans. High-risk infants constituted 7.6% of total resident births. Odds ratios for overall postneonatal mortality and sudden infant death syndrome in high-birth-score infants compared with low-birth-score infants were 6.2 (95% confidence interval [CI] = 4.2, 9.3) and 11.2 (95% CI = 5.4, 23.2), respectively. The relative risks of postneonatal mortality were similarly significant for infants with most clinical risk factors. During the program there was a 21.4% reduction in the trend of yearly standardized mortality ratios, which differed markedly from the trend in surrounding states. The data suggest that 33 lives were saved at a cost of $36,363 per infant.


Introduction

In 1982, an internal report for the West Virginia State Health Department (R.S.C. Pearson and R. Parkinson, Report to Infant Tracking Working Group, June 30, 1982) showed that many infants at great risk of postneonatal mortality received little or no medical care. Similar findings have been reported elsewhere in the United States, suggesting that many postneonatal deaths in socially disadvantaged groups are potentially preventable with adequate health care.

Based on results of previous studies, we hypothesized that systematically identifying infants at high risk of postneonatal mortality and ensuring that these infants received adequate health care would reduce mortality. So in 1985, because postneonatal mortality was excessive in West Virginia, we set up the first statewide system to identify, set care plans for, and track high-risk infants.

This report describes the significant drop in postneonatal mortality that followed.

Methods

Risk Identification

A preliminary retrospective study of postneonatal deaths in West Virginia (1980–1983), with four risk factors from the Sheffield Birth Score available on birth certificates, showed that 50% of the infants who died had scores above the 85th population percentile. This observation led us to adopt the entire Sheffield Birth Score as a risk predictor of postneonatal mortality in West Virginia.

At-risk infants were identified in two ways. First, all infants born in participating hospitals were scored according to the Sheffield Birth Score. Those scoring 530 or more (top 15%) were designated as high-score infants. Second, whether infants had been scored or not, physicians registered infants as high risk who had or developed any of the following clinical risk factors: (1) infant was the sibling of an infant who died of sudden infant death syndrome; (2) infant had an apparent life-threatening event; (3) infant had a tracheostomy; (4) infant had cardiac disease that put him or her at high risk for unexpected death; and (5) infant had a narcotic-addicted mother.

Interventions

Two intervention programs ran concurrently: one for each identification system. Infants with high scores were offered a specific schedule of physician visitation. Infants registered as clinically at risk were evaluated with a standard protocol, were designated “protocol infants,” and received various treatments including a home apnea and bradycardia monitor when appropriate.

Funding for the office visits of high-score infants and for testing and home monitoring equipment for protocol infants was prearranged with Medicaid and

At the time of the study, David Z. Myerberg, Cynthia F. Myerberg, Christine M. Britton, and Barry E. Fink were with the Department of Pediatrics, West Virginia University, Morgantown, WV. Robert G. Carpenter is with the London School of Hygiene and Tropical Medicine, London, England, and Charles W. Bailey is with the West Virginia Department of Health, Charleston, WV.

Requests for reprints should be sent to Christine M. Britton, West Virginia Birth Score Office, Department of Pediatrics, PO Box 9218, West Virginia University, Morgantown, WV 26506-9218.

This paper was accepted August 23, 1994.
third-party carriers. Neither intervention was randomized.

Program Development

The combined identification systems were initiated by educational programs at local hospitals. By 1987, 30 of the 34 West Virginia birthing hospitals and 620 associated physicians participated. At scoring hospitals, newborn-nursery nurses completed the birth-score card, which included data for matching with the birth certificate, and calculated the score. Parents of high-score infants were (1) informed by a nurse or physician that, based on the Sheffield Birth Score, their infants were at greater risk of health problems than were low-score infants; (2) asked to link with a primary care physician of their choice for six office visits in the next 6 months; and (3) required to sign a statement of understanding approved by the West Virginia University Institutional Review Board.

Score cards were mailed to the project office. For high-score infants, the office notified the chosen physician of the infant's risk status and supplied him or her with a growth chart that monitors both attained weight and weight gain over 2- and 8-week periods.

The protocol for the care of clinically at-risk infants was developed by an ad hoc statewide committee. The required educational program was available after February 1985 either in hospitals or for private study and included a posttest. A total of 229 physicians registered infants as clinically at risk.

Registered infants were evaluated with the protocol. Some were hospitalized locally, and some were transferred to a tertiary center. They received various treatments, which sometimes included the provision of home apnea and bradycardia monitors.

Record Linkage

Information from score cards, visits to physicians, and protocol investigations were entered into a UNISYS MAPPER database and linked to birth and death certificate data from the state health department. Death certificate data on West Virginia infants who died in other states were supplied by the National Center for Health Statistics. All West Virginia resident infants, whether or not they were included in the monitoring program, were tracked for 1 year for survival.

Program Evaluation

Exact tests of odds ratios, supplemented by logistic regression, were used to compare postneonatal mortality in various groups. Protocol registration increased with scoring. Because infants who were eligible for the protocol but who were not registered cannot be identified, the separate contributions to the reduction in mortality of physician linkage and the protocol cannot be determined.

Using US vital statistics,11 we evaluated the impact of the program on

*All registered live births.

FIGURE 1—Combined program of risk-related screening and intervention, West Virginia births, 1985 through 1987.

TABLE 1—Prevalence of Risk Factors from Birth Certificates in Scored and Nonscored Infants and Associated Relative Risk of Postneonatal Mortality (PNM)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Scored</th>
<th>Nonscored</th>
<th>Difference</th>
<th>Relative Risk of PNM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age &lt; 20 y</td>
<td>5251</td>
<td>6539</td>
<td>-12.8</td>
<td>1.0*</td>
</tr>
<tr>
<td>Education ≤ 8th grade</td>
<td>1392</td>
<td>1752</td>
<td>-25.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Single</td>
<td>6140</td>
<td>7609</td>
<td>-24.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Non-White</td>
<td>1373</td>
<td>1147</td>
<td>-16.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Pregnancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 2 previous</td>
<td>3827</td>
<td>4715</td>
<td>-9.7</td>
<td>1.0*</td>
</tr>
<tr>
<td>pregnancies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three or fewer prenatal</td>
<td>1354</td>
<td>1944</td>
<td>-5.9</td>
<td>1.0</td>
</tr>
<tr>
<td>clinic visits</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complications of pregnancy</td>
<td>2611</td>
<td>2983</td>
<td>-2.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Complications of labor</td>
<td>7636</td>
<td>10,546</td>
<td>-12.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Multiple birth</td>
<td>645</td>
<td>690</td>
<td>-5.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Infant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>15,909</td>
<td>19,727</td>
<td>-15.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Birthweight &lt; 1500 g</td>
<td>301</td>
<td>242</td>
<td>-14.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Apgar (5 min) &lt; 5</td>
<td>207</td>
<td>245</td>
<td>-13.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Birth defect(s)</td>
<td>324</td>
<td>435</td>
<td>-13.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>31,052</td>
<td>38,210</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note. The very small number of missing observations, averaging 0.5%, have been included in the largest category. *P < .05; ** P < .01.
postneonatal mortality in West Virginia by determining trends in standardized mortality ratios. We hypothesized that intervention would displace the underlying trend in standardized mortality ratios downward in West Virginia but not elsewhere. In 1985 and 1986, when the program was set up, it was assumed that the displacement would be a proportion of the shift in 1987 and 1988, computed as the proportion of postneonatal deaths expected among scored infants in those years, taking into account the month of birth and the distribution of deaths by age and month of birth.

Simulation studies indicate that standardized mortality ratios for 15 years before the start of intervention are needed to establish the trend in mortality with the sufficient certainty to ensure that, in the case of West Virginia, the analysis has 90% power for detecting a 20% drop in the postneonatal mortality rates at the 5% level.

Standardized mortality ratios (100 x observed/expected deaths) were therefore computed for each year from 1970 through 1988 for West Virginia; for two similar nearby states, Kentucky and Tennessee; and for the rural states of Idaho and Indiana. Because postneonatal mortality (PNM) for Blacks is higher than it is for non-Blacks, expected deaths were computed as follows:

\[(\text{Non-Black births} \times \text{US non-Black PNM rate}) + \text{Black births} \times \text{US Black PNM rate})/1000.\]

We included 1988 because 40% of infants who die postneonatally in 1 year were born the previous year, and the program continued without changes in 1988.

Trends in standardized mortality ratios were analyzed by logistic regression of observed postneonatal mortality rates with log (expected mortality rate) as an offset.

Analysis revealed that deaths reported for West Virginia in 1972 were inexplicably low (standardized residual = -4.13, \(P < 1.26 \times 10^{-4}\)) and so were excluded. Model parameters were insignificantly changed by doing so. There were no other outliers, and after excluding this observation, the test of the residual chi-square was not significant (\(P > 2.0\)).

Also, using a modification of Taylor and Emery's method, we classified deaths as inevitable when they were due to prematurity of less than 32 weeks of gestation with severe, unrelenting lung disease; cerebral degeneration; viral encephalitis; severe congenital viral or protozoa infection; severe cardiac or intestinal anomalies; myocarditis; Werdnig-Hoffmann disease; or lung hypoplasia. All other deaths were classified as either due to sudden infant death syndrome or possibly preventable. The classification was confirmed by review of hospital and physician records, postmortem reports, and family interviews when necessary and was available for all high-score and protocol deaths and low-score deaths thought to have been possibly preventable.

### Results

From January 1, 1985, through December 31, 1987, there were 69,262 births registered to West Virginia residents; the breakdown in relation to the two intervention programs is shown in Figure 1.

#### Birth Score

A total of 31,052 infants (45% of all births) were scored, of whom 4570 (14.7%) scored high. At the start, 1612 (4.4%) infants were scored incorrectly and were counted as not scored, among whom there were only two postneonatal deaths: one was a full-term boy who died of sudden infant death syndrome at 1 month of age, and the other, who was 14 weeks premature, died at 4 months of age from complications of prematurity.

Table 1, which compares birth certificates of 31,052 scored and 38,210 nonscored infants, shows that the scored group was at slightly higher risk in several respects, including birthweight. Figure 2 shows that the postneonatal mortality rate for scored infants was 14.1% lower than that for nonscored infants. After logistic covariance adjustment for the differences shown in Table 1, the postneonatal mortal-
ity rate for scored infants was 21.5% lower than that for nonscored infants ($P = .039$). The postneonatal mortality rate in high-score infants was 6.3 times greater than that in low-score infants ($P < .0001$). High-score infants linked with planned care had a postneonatal mortality rate 41.6% lower than that of high-score infants not linked with planned care ($P = .046$ by the one-sided exact test, which was appropriate because the possibility that intervention might increase mortality was not hypothesized). Tabulations showed that linked and nonlinked infants were similar with respect to most covariables, and after logistic covariance adjustment, the postneonatal mortality rate of linked infants was 50.0% less than that of nonlinked infants ($P = .014$).

Table 2 shows the predictiveness of the birth score in relation to sudden infant death syndrome and possibly preventable deaths. The specificity of the high score was 15% (i.e., the proportion of infants who were scored high). The sensitivity of the high score for sudden infant death syndrome was 66%, and for possibly preventable deaths, it was 45%. The mean (± SD) birth score for the population was 449 ± 78; for infants dying of sudden infant death syndrome, it was 563 ± 53; and for infants with possibly preventable deaths, it was 526 ± 68. Only 2 of the 32 infants dying of sudden infant death syndrome and 5 of the 35 infants with possibly preventable deaths had scores below the population mean. There were no sudden infant death syndrome or possibly preventable deaths in the 27% of the population with lowest scores.

### Protocol

Figure 1 shows that 1003 infants were registered statewide as protocol infants, constituting 1% of nonscored infants, 1.2% of low-score infants, 4.1% of high-score nonlinked infants, and 8.8% of high-score linked infants ($P < .0001$). Of these protocol infants, 375 were preterm and had an apparent life-threatening event and 390 were full term and had an apparent life-threatening event; 94 were siblings of infants who had died of sudden infant death syndrome; and 144 had tracheostomies, high-risk cardiac conditions, narcotic-addicted mothers, or combinations of these.

Table 3 shows postneonatal mortality by weight category for preterm and full-term infants who had an apparently life-threatening event, all protocol infants, and all other infants of comparable weight. Twenty two (21.9 per 1000) protocol infants died postneonatally (odds ratio = 7.3, $P < .0001$). Of the 22, 9 died of sudden infant death syndrome and six had possibly preventable deaths, so protocol infants had a statistically significant risk of sudden infant death syndrome and possible preventable death ($P < .001$). Preterm and full-term infants with apparently life-threatening events were significantly at risk of sudden infant death syndrome ($P < .05$), and full-term infants with apparently life-threatening events were significantly at risk of possibly preventable death ($P < .05$). Protocol postneonatal mortality rates were similar in non-scored, low-score, high-score, and linked groups ($P > .2$), but were lowest in the linked group.

### Overall Mortality

From 1970 through 1984, the standardized mortality ratios for West Virginia averaged 118.7 (95% CI = 113.4, 124.4). In 1987 through 1988, when the intervention program was established, the standardized mortality ratio was 96.1 (95% CI = 80.8, 114.4). The difference was 19.2% (95% CI = 3.9%, 32.1%; $P < .02$), which is not explained by a simple linear trend. In the nearby states of Tennessee and Kentucky, standardized mortality ratios were close to the state average in 1987 and increased in 1988. From 1970 through 1984 the average standardized mortality ratios for Tennessee and Kentucky were 110.7 and 101.9, respectively, which were significantly different from West Virginia's average ratio of 118.7, ($P < .001$). The underlying trend in the standardized mortality ratios was quadratic ($P < .01$), representing a slight fall in the mortality ratios in the early 1970s and a rise in the late 1980s. This trend was most apparent in the Tennessee standardized mortality ratios (Figure 3), but was similar in all three states ($P > .15$). With this model, the reduction in the standardized mortality ratios in West Virginia in 1987 through 1988 is described by a 21.4% downward displacement of the trend (95% CI = 8.2%, 31.5%; $P < .003$). This estimated effect of intervention is slightly larger than that given previously because it takes into account the upward trend in standardized mortality ratios in Tennessee and Kentucky in these years. Significance is also enhanced because this model also takes into account the fall in the West Virginia postneonatal mortality.
rate in 1985 and 1986, when intervention coverage was increasing (Figure 3).

Other Factors

Seven factors known to affect the incidence of postneonatal mortality were reviewed for changes in West Virginia during the study.15-17 These were the proportion of teenage mothers, mothers completing high school, mothers whose prenatal care started late, births to unmarried mothers, infants with a birthweight of less than 2000 or 2500 grams, average winter temperatures, and changes in public health programs. The proportions of both births to unmarried mothers and women with late prenatal care increased during the years of the program,17 and there were no reductions in these factors favoring postneonatal survival.18,19

The birth rate in West Virginia fell during the study. Three other primarily rural states (Idaho, Kentucky, and Indiana) had a similar decline in birth rate from 1979 through 1988.18 Postneonatal mortality in Kentucky and Indiana decreased in direct proportion to the trend in the US rate,11 so there was no downward trend in their standardized mortality ratios. In Idaho, the standardized mortality ratios increased by 0.5% per year.11 In none of these states was there any suggestion of a reduction in standardized mortality ratios such as was seen in West Virginia from 1985 through 1988.

Discussion

Before 1984, West Virginia postneonatal mortality was relatively high (P < .001). After the introduction of the risk-related intervention program in 1985, postneonatal mortality fell by 21.4% (P < .003), representing an estimated saving of 33 lives by December 1987 and 52 lives by the end of 1988. These estimates are clearly suggested by comparison of postneonatal mortality rates in scored and nonscored infants. Also, program benefits include increased awareness of and access to the protocol for all infants.20

When the program was set up, we knew from a pilot study and literature that both high-score and protocol infants were at increased risk. So ethically we could not justify a controlled trial involving withholding what is best described as "good medical care" from some high-risk infants. The West Virginia program, therefore, was set up as an uncontrolled field service program. The results are highly suggestive of program effectiveness.

To be effective, health care must be affordable, available, accessible, and acceptable to the patient and caregiver.1 We attempted to provide such health care for all infants identified as high risk by the program screening and linking procedures.

First, before screening started, funding sources for ambulatory visits, protocol workups, and home monitor equipment were ensured; so indigent families, about 50% in West Virginia, knew that care of their high-risk infant would be supported financially. Second, when high-risk infants were identified by score at birth or by clinical risk factors at the physician's office, physicians were available to carry out the appropriate prepared care plans.

Third, parents of high-score infants were linked with a physician of their choice. Also, the broad geographical base of the Ad Hoc Protocol Committee

---

FIGURE 3—Standardized mortality ratios of postneonatal mortality for West Virginia (WV), Tennessee (TN), and Kentucky (KY) together with estimated trends of these ratios.

Note. Displacement of the trend in West Virginia is shown after introduction of risk-related screening and intervention in 1985: a = expected trend if no intervention; b = fitted 21.4% downward displacement of the trend.
enabled physicians to refer infants for protocol workup to the tertiary-care center in their region. So care was acceptable to the family and the physician. Fourth, the fact that there were 620 physicians caring for high-score infants and 229 who identified protocol infants made care accessible statewide for all high-risk infants.

Thus, this program for high-risk infants met Patrick et al.'s criteria and attempted to maximize the use of appropriate health care. Only a large-scale, population-based program can effectively prevent the relatively small number of postneonatal deaths that are scattered throughout the community.

Prevention of postneonatal deaths was achieved by identifying 4570 high-risk infants by birth score, of whom nearly half (45.5%) attended visits with their chosen physician. Medicaid paid over $300,000 for these visits, which represented a marked improvement in care for high-risk infants, judging by a previous West Virginia report. The postneonatal mortality in this group (10.7 per 1000) warrants alerting parents and physicians to the infant's risk and expending funds to ensure high-quality ambulatory care of these infants.

The estimated reduction of 21.4% in the mortality of the high-score, linked group implies that the discriminating power of the score is underestimated by the odds ratio of 6.2, derived by comparing mortality in high-score and low-score groups. The odds ratio for mortality in nonlinked (i.e., untreated) infants compared with low-score infants is 7.7 ($P < .001$).

Because the score is continuous, the size of the high-score group can be chosen in the light of resources available. Theoretical issues in the optimal choice of cut point are discussed by Carpenter.15

The protocol for infants identified as clinically at risk enabled us to educate physicians in the community about risk, get funding for hospitalization and the purchase of equipment needed for evaluation and treatment, develop statewide standards of evaluation and care, test screening efficacy, and attempt to prevent postneonatal mortality. Any success was due to face-to-face education, predefined funding, collaborative effort, and coordinated data collection.

After protocol evaluation, infants were treated for their problems, and 522 (52%) were provided with home monitors at a cost to the state of $400,000, not including hospital, physician, prescription, and ancillary expenses.

The cost of intervention for both high-score and protocol infants must be added to setup, running, and administration costs. By the end of 1987 we estimated that 33 lives were saved at a cost of $1.2 million: $36,363 per life during the most costly period, when the program started.

Other groups have tried to prevent postneonatal mortality by implementing risk-related interventions on the basis of scoring.4-11 A meta-analysis of trends in standardized mortality ratios in 8 United Kingdom centers, which started score-based risk-related intervention programs between 1973 and 1988, showed that postperinatal mortality was reduced on average by 20.6% (95% CI = 8.6%, 31.1%; $P < .002$).12 Others have targeted clinically at-risk patients.13-15 Our program combined both methods into a broad-based, statewide system.

This program has been done on a smaller scale by Powell in Gosport and Portsmouth, England.26 The results in the Gosport/Portsmouth district were similar to our results in that there was a dramatic decline in postperinatal mortality from 1982 through early 1985 associated with the introduction of the combined risk-related intervention program. This program had some features that differed from ours. First, infants were scored at birth and then at 1 month. The 1-month score included both social factors and factors about apnea and feeding. Second, trained health-care visitors saw all high-risk infants regularly during the first 6 months of life. Third, criteria for evaluation of clinical risk factors and home monitoring were different from criteria used in West Virginia. Most important, however, the concepts of intervention for a small, high-risk proportion of the population were consistent in both programs.

The consistency of the reduction in mortality associated with these other programs strongly supports the conclusion that the reduction in mortality that occurred in West Virginia was a direct result of the risk-related intervention program. □

**Acknowledgments**

This research was supported by MCH SPRANS grant MCH543521, US Public Health Service, 1985 through 1988. An earlier version of this paper was presented at the 117th Annual Meeting of the American Public Health Association, Chicago, Ill, on October 23, 1989, and at the annual meeting of the American Academy of Pediatrics, October 13, 1992.

We thank Eileen Turbess for researching the infant deaths, Christine Dempsey for typing the manuscript, the State Department of Public Health for faith and financial support, and all participating nurses and physicians who volunteered their services.

**References**


