Cost-Benefit Analysis of Neonatal Intensive Care for Infants Weighing Less Than 1,000 Grams at Birth

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ABSTRACT. Cost-benefit analysis was performed on the care of 247 infants weighing between 500 and 999 g at birth, admitted to Women and Infants Hospital of Rhode Island between January 1977 and December 1981. The neonatal mortality was 68%. Eighty-seven percent of the survivors were evaluated neurodevelopmentally for 1 to 5 years: 74% were normal or minimally impaired, 10% were moderately impaired, and 16% were severely handicapped. Using these data in conjunction with cost information obtained from the hospital and therapeutic care facilities for handicapped children, total lifetime costs for the care of these infants were estimated. In 1982 dollars, present values of costs ranged from $362,992 per survivor for those weighing between 600 and 699 g to $40,647 per survivor for those weighing between 900 and 999 g, resulting in an inverse correlation between cost per survivor and birth weight ($P < .001$). We estimated present values of expected lifetime earnings per survivor, with a range of zero earnings for infants between 500 and 699 g, to $77,084 for those with birth weight of 900 to 999 g. It is concluded that from the standpoint of cost-benefit analysis as was used for this study population, neonatal intensive care may not be justifiable for infants weighing less than 900 g at birth. *Pediatrics* 1984;74:20–25; *economics, mortality, low-birth-weight infants, cost-benefit analysis, neonatal intensive care.*

The advent of neonatal intensive care has resulted in a significant reduction in neonatal mortality and morbidity.[1-3] Infants born weighing less than 1,000 g, however, still have mortality and morbidity that are significantly higher than infants of other weight categories.[1,3-5] They require prolonged hospitalization with care provided by highly trained personnel using expensive technology and instrumentation. Handicapped survivors may require continued medical and neurologic support, special education programs, and residential care. This short-term and long-term care results in significant financial expenditures, both for the individuals involved and for society.[6,7] In contrast, normal survivors become productive adults who contribute tangible and intangible benefits to society. The purpose of this report is to assess the costs and benefits of neonatal intensive care for infants weighing less than 1,000 g at birth.

MATERIALS AND METHODS

Over a 5-year period (Jan 1, 1977 to Dec 31, 1981), 247 infants weighing between 500 and 999 g at birth were admitted to the Neonatal Intensive Care Unit (NICU) at Women and Infants Hospital of Rhode Island. Of these, 159 (64%) were inborn, 84 (34%) were transported from 17 community hospitals, and four (2%) were admitted following home delivery. Birth weight ranged from 515 to 992 g.

The following data were obtained from the hospital charts: (1) neonatal survival and (2) duration of hospitalization. Hospital charges were available for 197 (80%) of the these infants and were adjusted to April 1982 dollar values using the medical care component of the Consumer Price Index, which was shown to be consistent with our actual increases in hospital charges. We assume that hospital charges adequately reflect hospital costs. For those infants whose hospital charges were unavailable, total hospital costs were estimated by extrapolating, within weight categories, from the hospital charges of the infants for whom the data were available.

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Seventy percent of the infants were cared for exclusively by hospital-based neonatologists and accordingly received no additional bills for physician services. The other 30% of the infants received additional care from private pediatricians and were therefore charged for physician services. The total physician costs for the latter group of infants were estimated by multiplying the daily fee for area pediatricians, supplied by Blue Shield of Rhode Island, times the duration of hospitalization.

Of the 78 survivors, 68 (87%) were enrolled in our follow-up clinic, where they were evaluated for neurologic and developmental performance at 4 and 8 months, and then at annual intervals. At the time this report was written, the latest neurodevelopmental assessments had been done at ages 4 months to 1 year for 14 infants, at age 2 years for 19 infants, 3 years for 14 infants, 4 years for eight infants, and 5 years for 13 infants. The neurodevelopmental results were classified by one of us (B.V.) using predetermined criteria as follows: (1) normal = no neurodevelopmental handicaps; (2) mild abnormality = myopia, strabismus, language delay, mild hearing loss, hyperactivity, and developmental quotient (DQ) of 80 to 85 by Bayley Scales of Infant Development up to 2 years of age or Stanford Binet at 3 to 5 years of age; (3) moderately abnormal = diplegia, hemiplegia, and DQ 65 to 80; and (4) severely abnormal = quadriplegia, blindness, deafness, hydrocephalus, uncontrolled seizures, and DQ of less than 65. If neurologic abnormality and DQ did not coincide, the child was placed in the lower category.

Infants with moderate and severe neurodevelopmental abnormalities are enrolled in Early Intervention Programs between birth and 3 years of age. At 3 years of age, they may be enrolled in special education programs at facilities like the Meeting Street School of Rhode Island and the Trudeau Center. These are nonprofit multidisciplinary facilities exclusively dedicated to the care and education of children with multiple handicaps. Mild to moderately handicapped children remain in these programs until age 5 to 7 years, at which time they may be "mainstreamed" into public education. Severely handicapped children require a special education program until 21 years of age. Group homes and sheltered workshops are available for noninstitutional care of severely handicapped adults.

The costs of long-term care for the handicapped are outlined in Table 1. All annual costs have been provided by the facilities (eg, Meeting Street School) and are taken as total expenditure per fiscal year divided by the number of subjects served; values are expressed in 1982 dollars.

Future costs are discounted to present value at time of birth. Following Boyle et al,[8] we use a discount rate of 5% per year. Costs incurred during the nth year of life are treated as if they occur at the end of that year. A cost (C_n) to be incurred during the nth year of life has a present discounted value of $C_n/(1.05)^n$. The present value of total lifetime costs is given by $\Sigma C_n/(1.05)^n$.

TABLE 1. Cost of Long-Term Care for the Handicapped

Type of Care	Moderately Handicapped		Severely Handicapped	
	Annual Costs/ Survivor	1982 Present Value	Annual Costs/ Survivor	1982 Present Value
Early intervention (age 0–3 yr)	$1,800	$4,902	$1,800	$4,902
Transitional (age 3–5 yr)	$12,000	$19,275	...	...
Meeting Street School (age 3–21 yr)	...	...	$12,000	$121,175
Group home residence (age 21 yr to death)	...	...	$10,000	$66,193
Present value of total lifetime costs	...	$24,177	...	$192,270

As indicated in Table 1, both moderately and severely handicapped infants are expected to participate in an Early Intervention Program for 3 years, at a cost of $1,800 per year. The present value of $1,800 per year for 3 years discounted at 5%, is $4,902. Moderately handicapped infants are expected to continue in a special education program for an additional 2 years, at $12,000 per year. The present value of this cost at the time of birth is $19,275. Severely handicapped infants are expected to continue to require the educational services of a center for the handicapped from age 3 years until age 21 years, at $12,000 per year. The "at-birth" present value of this cost is $121,175. We estimate that after age 21 years, half of the severely handicapped patients will reside in adult group homes. The cost of this care in Rhode Island averages $20,000 per year, making the expected cost per survivor $10,000 per year. The joint male-female life expectancy at birth is 73.3 years, so the duration of residence in a group home is estimated to be 52.3 years. The at-birth present value of a $10,000 per year cost for 52.3 years, starting at age 21 years, is $66,193.

To calculate economic benefits, we estimate expected lifetime earnings and reduce this to present value at time of birth. This is the methodology used by Boyle et al,[8] and it is also widely used in courts in the United States.[9] It is the most common approach to calculating the economic value of human life.[10,11] In our calculations, we assume that normal and mildly handicapped infants will have lifetime

earnings patterns that equal the average for the general population. We assume that moderately and severely handicapped infants will never be employable. These assumptions may introduce a small bias toward net economic benefits of mildly handicapped infants and against net economic benefits of moderately handicapped infants. However, the biases should be offsetting because the numbers of minimally and moderately handicapped infants are roughly comparable within weight classes.

To determine average lifetime earnings, we start with US Bureau of the Census data. The 1980 mean income of all persons in the United States, of both sexes, aged 14 and over, was $10,988.[12] To convert this to 1982 dollars, we multiply by the change in gross average weekly earnings in the private sector of the US economy.[13] The result is $12,487 per year. We project this annual income figure over a worklife expectancy of 37.8 years.[14] The hypothetical worklife starts at age 18 years. We discount future earnings using the discount rate of 5% per year. A sum (E_n) to be earned during the nth year of life has a present discounted value at the time of birth of $E_n/(1.05)^n$. The present value of total lifetime earnings is given by $\Sigma E_n/(1.05)^n$, where, for normal and mildly handicapped infants, $E_n = 0$ for $n = 1, \ldots, 18$, $E_n = \$12{,}487$ for $n = 19, \ldots, 56$, and $E_n = 0$ for $n \geqq 57$. (Adjustment is made for the fractional year of the 37.8-year worklife expectancy.) It follows that the present value of lifetime earnings, for normal and mildly handicapped infants, is $87,362.

TABLE 2. Neonatal Mortality and Duration of Hospitalization of Study Infants

Birth Weight (g)	No. of Infants	Survivors/Nonsurvivors	Mortality (%)	Duration of Hospitalization for Survivors/ Nonsurvivors (d)
500–599	15	0/15	100	0/3.77±7.7*
600–699	38	1/37	97	125/4.18±4.3
700–799	79	19/60	76	97.0±18.4/5.7±6.9
800–899	50	19/31	62	92.7±37.9/10.5±30.2
900–999	65	39/26	40	76.1±24.6/4.9±8.2

* Values are means ± SD.

RESULTS

Mortality

Mortality and duration of hospitalization of infants at 100-g increments are shown in Table 2. Mortality during the 5-year period ranged from 100% for infants between 500 and 599 g to 40% for infants between 900 and 999 g. χ^2 analysis ($n \times 2$) showed a significant correlation ($P < .001$) between birth weight and mortality. The correlation between the duration of hospitalization for nonsurvivors and birth weight was not significant; however, among survivors there was a significant correlation between duration of hospitalization and birth weight ($r = -.347$, $P < .05$ level).

Morbidity

The neurodevelopmental outcomes are shown in Table 3. Of the seven moderately handicapped children, one has mixed cerebral palsy with normal DQ, three have both motor and mental retardation, and three are retarded without physical handicap. Our severely handicapped children include four children with retrolental fibroplasia and cerebral palsy; five retarded spastic diplegics or quadriplegics; and two blind children, one of whom has a normal DQ.

Costs

The costs have been divided into three components: (1) hospital charges, (2) physician fees, and (3) charges for long-term care of handicapped survivors. Hospital charges are summarized in Table 4. All costs are in April 1982 dollars. Charge per day was consistent over the 5-year period. Linear regression analysis shows no significant correlation between birth weight and either total hospitalization charges or charge per day in the nonsurvivor groups. Among survivors in the 700- to 999-g groups, total hospitalization charges are not significantly correlated with birth weight; however, cost per day decreased significantly as birth weight increased ($r = -.270$ $P < .05$). Charges for the 600-

TABLE 3. Neurodevelopmental Status at Follow-up Visits of Study Infants

Birth Weight (g)	No. of Infants				
	Survivors	Seen in Follow-up	Normal + Minimally Handicapped	Moderately Handicapped	Severely Handicapped
500–599	...	...	...	...	...
600–699	1	1	...	...	1 (100%)
700–799	19	19	10 + 2 (63%)	2 (11%)	5 (26%)
800–899	19*	14	4 + 4 (57%)	2 (14%)	4 (29%)
900–999	39†	34	26 + 4 (88%)	3 (9%)	1 (3%)

* Three infants died at the neonatal stage; two were lost to follow-up.
† Five infants were lost to follow-up.

to 699-g survivor group were not used in the calculations for statistical significance, as the sample size was small.

Physician costs were calculated according to the average pediatrician charges in our state for care of hospitalized children. Physician fees account for 7% of the total costs for acute care. The cost per survivor by weight group was $3,398 for 600- to 699-g infants, $1,287 for 700- to 799-g infants, $1,171 for 800- to 899-g infants, and $1,024 for 900- to 999-g infants.

Costs for long-term care of handicapped infants per survivor were obtained by multiplying the proportions of handicapped infants in each weight group by the corresponding entries in Table 1. For example, in the 800- to 899-g group, 2/14 survivors in the study are moderately handicapped and 4/14 are severely handicapped; (2/14 × $24,177) + (4/14 × $192,270) = $58,388. As expected, long-term care costs are greatest for the 600- to 699-g group and decrease as birth weight increases. In Table 5, the first three columns were added together to give total lifetime costs per survivor. As can be seen, total lifetime costs per survivor are inversely related to birth weight.

Benefits

Economic benefits (average lifetime earnings per survivor) of surviving infants by birth weight are: 500 to 599 g, none; 600 to 699 g, none; 700 to 799 g, $55,138; 800 to 899, $49,887; 900 to 999 g, $77,031. Because we assumed normal and minimally handicapped infants will be fully employable whereas moderately and severely handicapped infants will be unemployable, economic benefits per survivor are found by multiplying $87,302, the present value of lifetime earnings for an average person, by the proportion of normal and minimally handicapped infants in each weight group. As there were no intact survivors in the 500- to 699-g categories, there are no economic benefits in those groups. Among infants weighing more than 700 g, however, the economic benefits increase; the maximum is seen in the 900- to 999-g weight category.

DISCUSSION

This report attempts to evaluate the costs and benefits of neonatal intensive care for infants weighing less than 1,000 g at birth. Although the mortality and long-term morbidity of this group of infants are high, many of the survivors are expected to become productive members of society and produce measurable economic benefits. Data for an analysis of this kind are limited[4,8,15] but useful, as such data provide adjunct information for comprehensive administrative decision making in the areas of funding allotments and ethical and medicolegal issues.

It has been suggested that the analysis of this kind of data is best done on a regional basis.[7] In Rhode Island, it is feasible to obtain reliable cost-benefit data for the following reasons: (1) Perinatal health care is well regionalized, with a single tertiary care center, Women and Infants Hospital, providing care to high-risk infants generated from a well-confined reproductive population base of 20,000 live births per year. (2) Our statistics (1977 to 1982) showed a 3% transfer rate of high-risk infants from the 17 community hospitals served by our center, indicating full and effective regionali-

TABLE 4. Hospitalization Cost for Study Infants

Birth Weight (g)	Hospitalization Charges		Hospital Charge (/d)		Hospitalization Cost/Survivor
	Survivors	Nonsurvivors	Survivors	Nonsurvivors	
500–599	...	$5,445 ± 8,188*	...	$799 ± 226	...
600–699	$44,800	$3,069 ± 2,977	$358	$969 ± 355	$167,324
700–799	$41,822 ± 15,928	$4,841 ± 4,364	$463 ± 220	$886 ± 272	$61,792
800–899	$32,123 ± 14,068	$7,591 ± 15,011	$418 ± 275	$856 ± 315	$41,797
900–999	$27,484 ± 13,708	$4,313 ± 5,883	$339 ± 112	$983 ± 380	$31,835

* Values are means ± SD.

TABLE 5. Cost Components for Study Infants

Birth Weight (g)	Hospital Cost/ Survivor	Physician Cost/ Survivor	Long-Term Care Cost/Survivor	Total Cost/ Survivor
500–599	...	...	...	...
600–699	$167,324	$3,398	$192,270	$362,992
700–799	$61,792	$1,287	$53,142	$116,221
800–899	$41,797	$1,171	$58,388	$101,356
900–999	$31,835	$1,024	$7,788	$40,647

zation of neonatal care.[14] (3) A follow-up program was established at Women and Infants Hospital in 1975 to evaluate all infants weighing less than 1,500 g at birth. For the current report, we have documented the neurodevelopmental outcome of 87% of survivors with birth weight of less than 1,000 g. (4) We are able to obtain hospital costs by retrieval of data from a computerized system. (5) A well-developed referral system exists that channels all handicapped children in our follow-up program into nonprofit facilities dedicated to the care of handicapped children, providing reliable therapeutic and educational cost data.

Our study shows an overall mortality of 68% for infants weighing between 500 and 1,000 g at birth. This finding is comparable to results reported by various other tertiary care units in the United States.[1,16–18] Our long-term morbidity statistics show 59% of the survivors to be normal, 12% minimally handicapped, 10% moderately handicapped, and 16% severely handicapped. Budetti et al[1] summarized morbidity statistics for this weight group using available literature and calculated that 74% of the survivors are normal, 15% are moderately handicapped, and 11% are severely handicapped. It is difficult to make precise comparisons of morbidity statistics in different studies because criteria and populations vary and sample sizes tend to be small. Nevertheless, our morbidity results are similar to those of Budetti et al. Because the mortality and morbidity results in our study are similar to those in other studies, the cost-benefit analysis of care for this group of infants is suggestive of costs and benefits on a national basis.

A cost-benefit analysis, in simple terms, is an effort to assess the negative and positive economic consequences of a specific policy, event, or set of facts. Its use to evaluate neonatal intensive care cannot be precise as it relies on projections of future costs and earnings that are to a certain extent speculative. Likewise, projections of long-term morbidity based upon early follow-up data may yield some errors.

Several comments about the cost estimates in our cost-benefit analysis can be made. In an ideal cost-benefit analysis,[13] costs would include: (1) costs of neonatal intensive care, (2) long-term medical care costs, (3) lifetime cost of comprehensive care for handicapped infants, and (4) intangible costs. The true costs of neonatal intensive care may not be accurately reflected by hospital charges and physician fees. For instance, there may be cross-subsidization among hospital units; the neonatal intensive care unit may be subsidizing the normal infant nursery, or vice versa.

Many survivors of neonatal intensive care have long-term medical problems in addition to their neurodevelopmental deficits. For example, at least 10 survivors required surgery after discharge. Costs such as these were not included in our analysis because it is difficult to obtain accurate data on them or to predict future requirements for such care.

Lifetime costs of educational programs for handicapped survivors or for group home residents were calculated from the status of the child at the last follow-up visit. Our rate of referral to Early Intervention Programs and to the Meeting Street School is accurate. However, the incidence of placement in adult group homes is speculative. We estimate that half of the severely handicapped survivors may need such care. We feel this is a conservative estimate. The other half could remain with their families. This study does not include the expenses incurred or the potential earnings lost by the survivors' families for such support. Last, the intangible costs of pain, sorrow, and disruption to the individual and his family are not included here.

Several comments about the benefit estimates in our cost-benefit analysis can be made. In an ideal cost-benefit analysis, benefits would include: (1) the value of improved mortality statistics attributable to neonatal intensive care, (2) the value of projected earnings of survivors, and (3) intangible benefits.[19] Several authors have suggested that neonatal intensive care has resulted in improved mortality and morbidity statistics, and therefore more productive survivors and fewer handicapped ones.[3,7,16] However, other authors feel this is not true. In this paper, we have not addressed this issue.

With regard to our estimates of lifetime earnings: these projections may be affected by assumptions about average annual earnings, the discount rate, and the worklife expectancy. We have been conservative about annual earnings and the worklife expectancy. We have repeated this analysis with alternative discount rates of 3% and 0% per year. With both alternative rates the qualitative results remain the same: for infants in all weight classes less than 900 g, total costs per survivor exceed average lifetime earnings per survivor, whereas for infants in the 900- to 999-g class, average lifetime earnings per survivor exceed total costs per survivor.

The intangible benefits of neonatal intensive care also include the joy of the parents and relatives of the surviving low-birth-weight infants, and the advancement of medical knowledge associated with neonatal intensive care that may lead to reductions in both mortality and morbidity in the future. This study does not try to measure these benefits.

In spite of its drawbacks, our study points to

some real issues of costs and benefits of neonatal intensive care. Infants weighing more than 900 g have a greater than 50% chance of survival, an 85% chance of developing normally, and average lifetime earnings per survivor in excess of total costs per survivor. Infants weighing less than 900 g, however, have high mortality with considerable morbidity, and their total costs per survivor are in excess of total lifetime earnings per survivor. This is in accordance with the study of Britton et al.[20] Unlike the study of Boyle et al,[8] this paper does not compare outcomes under neonatal intensive care with outcomes without neonatal intensive care. Our results should be seen in that light: they indicate that neonatal intensive care for low-birth-weight infants (less than 900 g) results in costs that exceed benefits, but they do not appraise the alternatives.

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