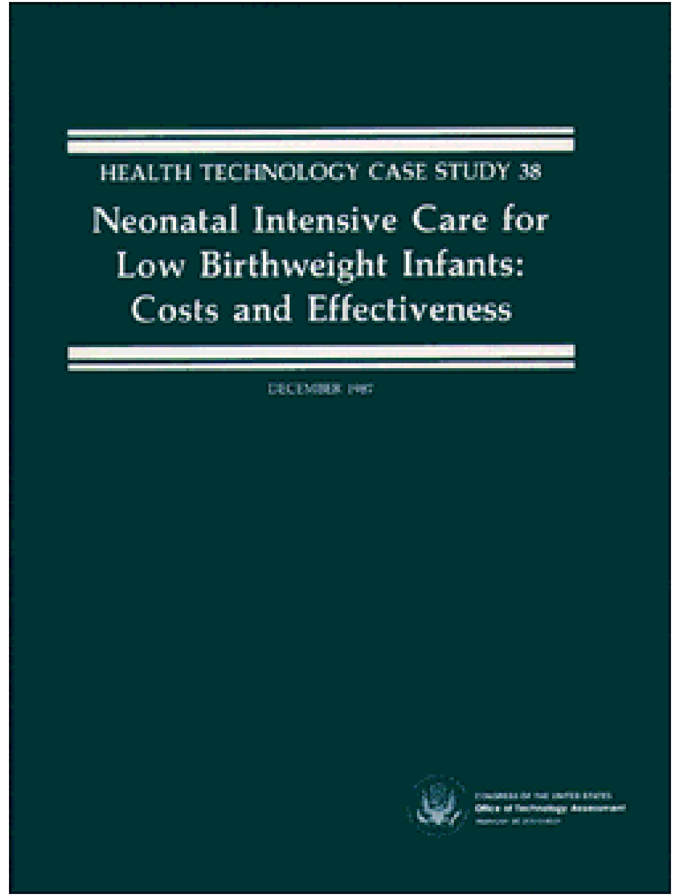
Neonatal Intensive Care for Low Birthweight Infants: Costs and Effectiveness

December 1987

NTIS order #PB88-158902



Recommended Citation:

U.S. Congress, Office of Technology Assessment, *Neonatal Intensive Care for Low Birthweight Infants: Costs and Effectiveness* (Health Technology Case Study 38), OTA-HCS-38 (Washington, DC: U.S. Congress, Office of Technology Assessment, December 1987). This case study was performed as part of OTA's assessment of *Healthy Children: Investing in the Future.*

Library of Congress Catalog Card Number 87-619883

For sale by the Superintendent of Documents
U.S. Government Printing Office, Washington, DC 20402-9325
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Preface

Neonatal Intensive Care for Low Birth weight Infants: Costs and Effectiveness is Case Study 38 in OTA's Health Technology Case Study Series. This case study has been prepared in connection with OTA's assessment, *Healthy Children: Investing in the Future,* which was requested by the House Energy and Commerce Committee and the Senate Labor and Human Resources Committee.

OTA case studies are designed to fulfill two functions. The primary purpose is to provide OTA with specific information that can be used in forming general conclusions regarding broader policy issues. The first 19 cases in the Health Technology Case Study Series, for example, were conducted in conjunction with OTA's overall project on *The Implications of Cost-Effectiveness Analysis of Medical Technology*. By examining the 19 cases as a group and looking for common problems or strengths in the techniques of cost-effectiveness or cost-benefit analysis, OTA was able to better analyze the potential contribution that those techniques might make to the management of medical technology and health care costs and quality.

The second function of the case studies is to provide useful information on the specific technologies covered. The design and the funding levels of most of the case studies are such that they should be read primarily in the context of the associated overall OTA projects. Nevertheless, in many instances, the case studies do represent extensive reviews of the literature on the efficacy, safety, and costs of the specific technologies and as such can stand on their own as a useful contribution to the field.

Case studies are prepared in some instances because they have been specifically requested by congressional committees and in others because they have been selected through an extensive review process involving OTA staff and consultations with the congressional staffs, advisory panel to the associated overall project, the Health Program Advisory Committee, and other experts in various fields. Selection criteria were developed to ensure that case studies provide the following:

- examples of types of technologies by function (preventive, diagnostic, therapeutic, and rehabilitative);
- examples of types of technologies by physical nature (drugs, devices, and procedures);
- examples of technologies in different stages of development and diffusion (new, emerging, and established);
- examples from different areas of medicine (e.g., general medical practice, pediatrics, radiology, and surgery);
- examples addressing medical problems that are important because of their high frequency or significant impacts (e. g., cost);
- examples of technologies with associated high costs either because of high volume (for low-cost technologies) or high individual costs;
- examples that could provide information material relating to the broader policy and methodological issues being examined in the particular overall project; and
- examples with sufficient scientific literature.

Case studies are either prepared by OTA staff, commissioned by OTA and performed under contract by experts (generally in academia), or written by OTA staff on the basis of contractors' papers.

OTA subjects each case study to an extensive review process. Initial drafts of cases are reviewed by OTA staff and by members of the advisory panel to the associated project. For commissioned cases, comments are provided to authors, along with OTA's suggestions for revisions. Subsequent drafts are sent by OTA to numerous experts for review and comment. Each case is seen by at least 30 reviewers, and sometimes by 80 or more outside reviewers. These individuals may be from relevant Government agencies, professional societies, consumer and public interest groups, medical practice, and academic medicine. Academicians such as economists, sociologists, decision analysts, biologists, and so forth, as appropriate, also review the cases.

Although cases are not statements of official OTA position, the review process is designed to satisfy OTA's concern with each case study's scientific quality and objectivity. During the various stages of the review and revision process, therefore, OTA encourages, and to the extent possible requires, authors to present balanced information and recognize divergent points of view.

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[b]Original publication numbers appear in parentheses.

[c]The first 17 cases in the series were 17 separately issued cases in *Background Paper #2 Case Studies of Medical Technologies*, prepared in conjunction with OTA s August 1980 report *The Implications of Cost-Effectiveness Analysis of Medical Technology},*

[d]Background paper #3 t. The *Implications Of Cost-Effectiveness Analysis of Medical Technology.*

[e]Background Paper #5 to *The Implications of Cost-Effect] veness Analysis of Medical Technology*

[f]Background Paper #1 to OTA's May 1982 report *Technology and Handicapped People.*

[g]Background Paper #2 to *Technology and Handicapped Peep/e*

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NOTE: OTA gratefully acknowledges the members of this advisory panel for their valuable assistance and thoughtful advice. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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Summary and Conclusions

INTRODUCTION

Neonatal intensive care is defined by the American Academy of Pediatrics as the constant and continuous care of the critically ill newborn (2). Although modern, high-technology neonatal intensive care units (NICUs) are a relatively recent innovation, their widespread application has already played a major and definitive role in the improved survival of low birthweight and premature infants (25). Despite this success, ethical and economic concerns remain about this technology. Because of intensive care, some infants, who previously would have died, survive but with serious and permanent handicaps. The double-edged sword of technology, at ever-increasing costs, both saves and disables babies. This case study reviews the evidence on the effectiveness of neonatal intensive care and addresses a number of these related issues:

- What are the chances of serious handicap among surviving very low birthweight infants as mortality declines?
- What changes in technology and medical practices are and will affect the chances for survival and good developmental outcome?
- How are decisions made about treatment for extremely premature infants who are at the edge of viability?
- How much does neonatal intensive care cost? Who pays for treatment, and are there problems with reimbursement?
- Is there unequal access to neonatal intensive care? What are the barriers that may prevent entry for some babies?
- What are the long-term economic consequences of providing neonatal intensive care?

Scope of the Case Study

Up to half of all patients in neonatal intensive care are normal birthweight infants with congenital anomalies, pneumonia, or other problems. However, this case study limits discussion to low birthweight infants (<2500 grams) for several reasons. First, low birthweight infants, particularly

Photo credit: March *of Dimes Birth Defects Foundation*

those with birthweights below 1500 grams, are at the greatest risk for high mortality and morbidity. Moreover, outcomes are changing most rapidly for these infants, and new technologies currently under investigation hold promise for continuing improvements in the future. Second, there appears to be a shift in the patient population in neonatal intensive care, with increasing numbers of beds occupied by extremely low birthweight infants. Difficult ethical, social, and economic judgments are involved in the decision to treat these infants. Finally, because low birthweight and low socioeconomic status are associated, it is likely that public payment programs pay a substantial portion of the expense for neonatal intensive care.

Throughout this case study, the term "low birthweight infant" is used to refer to infants who weigh less than 2500 grams at birth.[1] "Very low birthweight infant" refers to infants with birthweights of less than 1500 grams, and "extremely low birthweight infant" describes infants who are born weighing less than 1000 grams. Gestational age is likely more important than birthweight in determining outcome, but the two are highly correlated. Birthweight is easier and more reliable to

'For ease of reference, 2500 grams is approximately 5 lb 5 oz; 1500 grams is about 3 lb 3 oz; and 1000 grams is about 2 lb 2 oz.

measure, and most of the medical literature and available data focus on birthweight alone. That bias is reflected in this review.

Under the regionalization concept first introduced in the mid-1970s, the most sophisticated neonatal intensive care is provided in so-called Level 111 hospitals. Level II hospitals also provide intensive care services but lack some of the components and expertise of Level III units, while Level I hospitals provide only normal newborn care. The extent to which high-risk mothers and infants are referred to and treated at the appropriate level of care is addressed in this study.

Organization of the Case Study

Findings and conclusions about the costs and effectiveness of neonatal intensive care are summarized in the remainder of chapter 1. Chapter 2 inventories the national supply of neonatal intensive care units and describes recent trends in use and costs. Chapter 3 reviews mortality and handicap rate: over time and discusses the outlook for the three clinical problems that account for a majority of the deaths and poor outcomes among very low birthweight infants (respiratory distress syndrome, intraventricular hemorrhage, and retinopathy of prematurity). Problems in financing neonatal intensive care, with special emphasis on Medicaid policies and expenditures, are reviewed in chapter 4. Then, findings of unequal mortality risks in different types of hospitals are reviewed, and possible inequities in access to neonatal intensive care are considered (ch. 5). Competitive and financial constraints on hospitals and physicians, as well as ethical considerations, are explored. Finally, chapter **6** analyzes the lifetime economic implications of neonatal intensive care for very low birthweight infants and for society.

SUMMARY

Supply, Use, and Costs

Between 150,000 **and 200,000 infants (4 to 6 percent of all newborns) are treated annually in** NICUs, **and at least one-half of them are low birthweight infants.** Confusion over which hospitals deliver the most intensive v. less specialized care complicates estimates of the supply of neonatal intensive care. Of a total of **534** combined Level II and Level 111 neonatal intensive care units in the country, about 420 of them offer very sophisticated Level III services. While many individual neonatal intensive care units are filled to overcapacity, there does not appear to be a shortage of NICUs or intensive care beds nationwide. In 1983, the occupancy rate for NICUs was 73 percent, comparable to the national occupancy rate for all hospital beds.

Neonatal intensive care for very low birthweight infants ranks among the most costly of all hospital admissions. Although the average hospital cost for low birthweight infants ranges from only **$12,000** to **$39,000,** the distribution of costs among patients in the neonatal nursery is highly skewed. A few infants incur truly extraordinary costs. About half of the variation in costs is explained by four risk factors: birthweight, survival to hospital discharge, use of assisted ventilation, and surgical intervention. **A primary predictor of cost is birthweight; costs increase as birthweight falls.** The average cost for a very low birthweight survivor is from **$31,000** to $71,000. The tiniest infants who survive, those with birthweights under **750** grams, have the longest average hospital stays, about **98** days, and the highest costs, averaging **$62,000** to **$150,000.** Hospitals report increasing numbers of these tiniest babies in their NICUs. (About 8,500 infants weighing less than 750 grams are born each year in the United States.)

Mortality and Morbidity

Neonatal intensive care, along with improved obstetrical practices, is in large part responsible for the remarkable decline in birthweight-specific neonatal mortality rates over the past 25 years. Neonatal mortality for infants with birthweights of 1000 to 1500 grams has fallen from more than 50 percent to only 10 percent. And whereas more than 90 percent of all infants weighing under 1000 grams died in *1960*, the neonatal mortality rate for this group now is about 50 percent. This achievement reflects improvements primarily in the 750- to 1000-gram birthweight group (more than two-thirds survive today), because mortality in the smallest and most premature infants, those under 750 grams, is still very high.

Even **among the most sophisticated neonatal intensive care centers, the risk of mortality for very low birthweight infants varies substantially.** In the mid-1980s for example, the mortality rates reported for the most vulnerable group, infants with birthweights under 750 grams, varied from 28 percent in one university-affiliated center, to **53** percent in another, and 74 percent in a third center. The success of some centers indicates that the technology of neonatal intensive care is changing very rapidly.

The rate of serious long-term disability increases with decreasing birthweight, but within each birthweight group, the proportion of NICU survivors who have serious handicaps has not changed significantly since the introduction of neonatal intensive care. Because many very sick newborns who previously would have died are now surviving, an increasing rate of handicap might have been expected. OTA **concludes that neonatal intensive care has contributed to improved long-term developmental outcomes for premature infants. The great decline in mortality among all subgroups of very low birthweight infants over the last 10 years, however, means there are now larger absolute numbers of both seriously handicapped and normal survivors.** For every 100 very low birthweight infants treated in today's NICUs, about **27** will die before hospital discharge, 16 will be seriously or moderately disabled, and 57 will be normal children, though some will develop mild learning disabilities.

The majority of deaths in the extremely low birthweight group are attributable to respiratory distress syndrome (RDS) or intraventricular hemorrhage. The incidence of both these clinical problems, -as well as the incidence of retinal disease, increases with progressively lower birthweights. About half of all very low birthweight infants have RDS, and one-third have brain hemorrhages. Infants with severe hemorrhage have both high mortality and, for those who survive, a high rate of later neurodevelopmental disability. Retinal disease, which is almost entirely restricted to very low birthweight infants, causes blindness in about 1 percent of infants with birthweights between 1000 and 1500 grams and in about 5 to 11 percent of infants with birthweights below 1000 grams.

RDS is the most common problem in the neonatal nursery, and assisted mechanical ventilation is usually essential to help babies in respiratory distress breathe. But the use of assisted ventilation is correlated with both intraventricular hemorrhage and the development of chronic lung disease. One-third of very low birthweight survivors have chronic lung disease at 1 month of age. A recent study showed that the way in which ventilator support is medically managed may be associated with outcome; some neonatal intensive care centers have significantly lower rates of chronic lung disease than others. **Changing and refining existing medical practices in NICUs could further decrease the mortality and poor outcomes associated with RDS and assisted ventilation.**

Moreover, it is possible that **several technologies could substantially prevent RDS in the future.** Steroid treatment, administered to women in preterm labor in order to accelerate fetal lung maturation, has been available for 16 years. Despite numerous studies confirming its efficacy, however, many obstetricians have concerns about specific indications for use, and steroid treatment has not been widely integrated into obstetrical practices. The other technology, administering exogenous pulmonary surfactant into the lungs of the newborn, is new, and the medical community is hopeful about its potential for treating lung deficiency. Controlled clinical trials conducted to date have demonstrated lowered risk of death and respiratory disease. It will be several more years before surfactant therapy is generally available for premature infants.

Financing

A study in children's hospitals (some of the most sophisticated Level III centers) found **that neonatal intensive care is the most costly category of service to provide, and that these hospitals suf-**

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fer their greatest financial losses from neonatal cases. In those hospitals studied, neonates represented only 8 percent of admissions but 21 percent of all patient days and 25 percent of the hospitals' costs.

As third-party payers, including Medicaid, increasingly move to prospective payment methods, concerns have been raised that diagnosis-related groups (DRGs) as currently constituted under Medicare do not adequately reimburse hospitals' costs in providing neonatal intensive care. As many as half of the admissions to NICUs are classified as outliers (cases with statistically unusual lengths of stay) under the current Medicare system. **Reform of the DRG system to reflect more accurately the true resource use of very low birthweight infants will help hospitals' finances, but hospitals may continue to experience revenue shortfalls for neonatal intensive care because of their inability in the future to shift costs as the proportion of charge-paying patients declines.**

Medicaid is generally considered a poor payer by hospitals. The method of reimbursement and the level of payment for neonatal intensive care varies by State. Likewise, the proportion of Medicaid admissions, and therefore Medicaid's importance as a payer, varies widely across institutions; overall, Medicaid recipients account for about a quarter of all NICU admissions. From the perspective of the Medicaid program, about 6 percent of all newborns whose deliveries are subsidized by Medicaid require neonatal intensive care, but this care is so expensive that it represents about *30* percent of all Medicaid expenditures for maternity care. Through recent legislative changes, any newborn whose mother met income requirements for Medicaid prior to delivery is assured of at least 60 days automatic Medicaid coverage. Financial coverage for other infants in the NICU who are not eligible for Medicaid is sometimes available through a variety of State and county payment programs for the indigent.

Access

The statistics on survival and outcome that are cited in this case study refer to infants who are treated in the regional perinatal centers (Level III hospitals). A number of studies document better survival rates for very low birthweight infants born in Level III hospitals than for those born elsewhere in the same geographic area. Moreover, several studies go further and indicate that **survival rates for very low birthweight infants born in Level III hospitals are significantly higher than for those infants born in either Level I or Level II hospitals, despite transfer of sick infants after birth.** Because deaths within a short time of birth cannot be influenced by infant transport, it may be that very low birthweight infants are not adequately resuscitated and stabilized at birth in Level I hospitals. Poorer survival rates in Level II hospitals were reported in only a few studies. The Level II hospitals with poorer survival rates rarely referred their very low birthweight patients to regional centers, and the researchers concluded that the intermediate units could not expertly manage the complications of low birthweight, such as respiratory failure.

Because little is known about whether high-risk mothers and infants are actually redistributed to the appropriate level of care, the observed gradient in mortality risk across hospital level could indicate possible inequities in the provision of neonatal intensive care. Although the contribution of infant transport cannot be assessed, one indication of access to intensive care is the extent to which high-risk deliveries are concentrated in Level III centers. All published reports indicate that although **high-risk deliveries have increasingly been moved to Level III centers over time, there is still wide variation among geographic areas.** Rural populations, as expected, clearly have less access to perinatal centers than urban populations, and one study showed better access to specialized care for black infants than for white infants.

Although the extent of a possible access problem cannot be determined from existing data sources, **hospitals may have financial incentives not to serve high-risk mothers and infants.** Hospitals have no legal obligation to admit these patients even if they are perinatal centers, and some hospitals suffer their greatest financial losses from neonatal cases. Medicaid coverage for very low birthweight infants does not guarantee admission, because Medicaid is generally considered a poor payer by hospitals. The same financial incentives operate for physicians with regard to nonpaying or partial-pay patients. Obstetricians lag behind other specialties in the extent to which they accept Medicaid patients.

A more important barrier to treatment, however, is the unwillingness of many obstetricians to refer high-risk maternity cases to perinatal centers prior to delivery. **The perceptions of obstetricians, many of whom substantially underestimate the potential survival of extremely low birthweight infants, influence the management of high-risk pregnancies and premature labors, which, in turn, actually affects the survival of newborns. On the other hand, once a low birthweight infant, no matter how tiny and premature, is admitted to an NICU, aggressive treatment is almost always assured.** Neonatologists, in part in reaction to legal liability concerns raised by "Baby Doe" rules, are increasingly treating even the tiniest infants born at the threshold of viability. The probability of handicap cannot be determined at birth, and the normal outcome for a few of these infants encourages neonatologists to push for the unprecedented treatment of the lowest birthweight infants.

Cost-Effectiveness

The incremental cost of neonatal intensive care to produce a survivor in 1984 was $86,000 for infants with birthweights between 1000 and 1500 grams and $118,000 for infants with birthweights below 1000 grams. The long-term economic consequences of providing neonatal intensive care to very low birthweight infants were evaluated in a cost-effectiveness study performed by Canadian researchers. Projected over a lifetime, the introduction of neonatal intensive care costs **$4,460** per quality-adjusted life-year gained for infants with birthweights between 1000 and 1500 grams and $31,240 per quality-adjusted life-year gained for infants with birthweights under 1000 grams. **Thus, neonatal intensive care results in both increased survival and increased costs. Moreover, neonatal intensive care becomes more expensive as it is employed in increasingly marginal cases.** The worth of a life saved, however, is ultimately a value judgment involving ethical and social considerations. The results from cost-effectiveness studies alone cannot guide decisions regarding who should receive care.

CONCLUSIONS

This OTA case study corroborates earlier reports concluding that neonatal intensive care is an effective technology for the improved survival and long-term developmental outcome of very low birthweight infants. **In the 1980s, continued improvements in outcomes are shown in every very low birthweight subgroup, with the greatest statistical improvement, recently, in the 750- to 1000-gram birthweight group.**

The success of neonatal intensive care does carry a burden of increasing numbers of seriously handicapped children, As mortality **rates decline, there are larger absolute numbers of both handicapped and normal survivors.** If today's neonatal intensive care were provided for all very low birthweight infants, over 15,000 normal children who would have died in 1975 would be added to the Nation's population. Likewise, families and society would face an increase of about 2,200 seriously handicapped infants who would not have survived a decade ago, These individuals require outside resources and help throughout their lifetimes.

Neonatal intensive care is costly. While the average hospital cost for low birthweight infants is about **$620 per** day in the hospital, a few infants incur truly extraordinary costs. The cost to society increases as neonatal intensive care is provided to the very lowest birthweight infants, but it would be unethical and illegal categorically to deny treatment. So **far, technology cannot determine at birth which infants are doomed to severely handicapped lives.** Physicians, in *conjunction* with parents, have traditionally grappled with decisions about treatment for premature and sick newborns—and they must continue to do this.

The disturbing fact is that **an extremely premature baby's chances for survival and normal development are in large part determined by where the baby is born.** While moderately sized low birthweight infants do well in Level II units, there is a gradient in mortality risk across hospital level for very low birthweight infants. Although the birth of a premature infant cannot always be anticipated, there is ample evidence that a pregnant woman at high risk should be transferred to a Level III center prior to delivery. Very low birthweight infants should be transported to Level III hospitals as soon as they are stabilized.

The extent of a possible problem in access to neonatal intensive care is unknown. Regional organization may have proceeded further in neonatal care services than in any other aspect of medicine in this country. This regionalization has been accomplished, in almost all States, through the voluntary cooperation of hospitals, physicians, and maternal and child health officials. Moreover, the optimum concentration of high-risk births in Level III centers is unknown because of unavoidable hurdles to admission (e.g., access to services in rural areas will always lag behind availability in urban areas).

It does appear, however, that some **high-risk mothers and infants are not transferred to Level III hospitals for financial reasons. It also appears that some Level II hospitals are not appropriately transferring high-risk women and newborns because of a desire to offer competitively a full array of services even when those services do not meet the needs of the patients. And** most importantly, surveys show that **many obstetricians and pediatricians do not have a good understanding of the prognosis for extremely low birthweight infants;** they substantially underestimate the potential for survival and normal outcome. Their management of high-risk pregnancies and births reflects these misunderstandings.

These problems point to a **need to continue to push for further regionalization of perinatal services in the 1980s. Stronger guidance from professional associations and State health authorities may be necessary** in two areas. One is the formulation of clear recommendations on treatment and transfer policies for infants with particular problems and/or birthweights by level of *care.* Second is the exercise of leadership in informing obstetricians and pediatricians about current practices and outcomes in neonatal intensive care.

Even among Level III hospitals, there are substantial differences in mortality risk for very low birthweight infants. At present, there is only suggestive evidence that variations in medical practices within institutions may lead to these differences. Differences in the organization of NICUs, the methods of applying existing technologies, and the use or disuse of certain technologies may all play a part in the success of some centers. Clearly, the technology of neonatal intensive care is changing very rapidly. **The rate of diffusion of the latest and most effective techniques and knowledge—even among the 420 most sophisticated NICUs offering Level III services—may not be proceeding apace with developments.**

The problem of disseminating information to medical professionals and institutions is not unique to neonatal intensive care. The need to share information among professionals is ongoing in all arenas of medicine. Moreover, skepticism about new ideas and techniques is healthy in that the diffusion of technologies which are not efficacious is at least slowed. Further research in NICUs is definitely necessary to evaluate which medical practices are effectively helping very low birthweight infants. Nevertheless, the speed of technology diffusion in neonatal intensive care is critical because the lives and well-being of our smallest babies may hang in the balance.

Chapter 2

Supply, Use, and Cost of Neonatal Intensive Care

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Supply, Use, and Cost of Neonatal Intensive Care

INTRODUCTION

With the evolution of perinatal medicine and the development of associated medical technology in the 1960s, many hospitals introduced neonatal intensive care units (NICUs). Intensive care units for adults had already been established in most hospitals, and the similar needs of newborns for sophisticated, intensive treatment became apparent (15). In the United States, the primary growth in special units for neonatal intensive care, combining high technology and highly trained staff, occurred in the 1970s. By 1976 the Committee on Perinatal Health[1] had proposed guidelines for the regionalization of maternal and perinatal health services that included a three-tiered system of hospital care (34). Level III hospitals serve as regional centers and provide the most intensive neonatal care. Level II facilities have many but not all components of newborn intensive care services, and Level I hospitals provide normal newborn care with no special units for the care of seriously ill infants. The concept of regionalization is that high-risk mothers and infants are screened and referred or transported to the appropriate level of care. Success depends on the coordinated relationship among hospitals in the system.

[1]The Committee on Perinatal Health was a joint effort by the American Medical Association, the American College of Obstetricians and Gynecologists, the American Academy of Family Physicians, and the American Academy of Pediatrics.

Despite these guidelines, recommendations published by the American Academy of Pediatrics in 1977 (2), and guidelines jointly issued by the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists in 1983 (4) outlining the responsibilities and requirements of the three hospital levels, there is no standard national application of what constitutes Level II or Level III care **(25).** Some States evaluate each hospital's perinatal services and assign levels. In other States, the regional system is informal, and each hospital classifies its own services. An earlier study by OTA on neonatal intensive care identified only four States in 1978 that forced adherence to specific standards through licensure or certificate-of-need authorities (25),

SUPPLY

The confusion over which hospitals deliver intensive v. less specialized newborn care complicates data collection and analysis. As a definitional minimum, Level III NICUs have the capability to provide ongoing respiratory support and are staffed by a full-time neonatologist. But today many Level II units also have these capabilities. The true distinction between the two levels of care may lie with the kinds of patients treated, rather than in equipment and staffing capabilities. Level II hospitals are more likely to provide short-term respiratory support, stabilize very sick or very preterm patients, and then refer more complicated cases, especial y those requiring surgery, to Level 111 units (144)

Because of these ambiguities, most inventories group Level II and Level III hospitals together. Table 1 presents the most recent estimate of the combined number of Level II and Level III units identified by the National Perinatal Information Center in a survey of hospitals offering perinatal and neonatal special care. The reported 1983 totals of **534** NICUs and **7,684** NICU beds represent a nationwide increase of 3 percent in available neonatal intensive care beds and a decrease

Photo credit: Children's Hospital National *Medical Center, Washington, DC*

Level III hospitals provide the most sophisticated intensive care for newborns.

of 13 percent in the number of NICUs since an earlier OTA assessment estimated the number of units and beds in 1978 (25). To illustrate the confusion over definitions, Ross Laboratories, which initially surveyed hospitals in 1978 and then informally updated its inventory, lists more than twice as many Level II and Level III hospitals (1,137) on its 1986 roster (138). In part, this difference is accounted for by the inclusion in the Ross

Table I.—Supply of Neonatal Intensive Care Units (NICUs) and Beds in the United States, 1983

Region	Number of hospitals	Number of NICU beds
Northeast	100	1,622
South Atlantic	81	1,003
North Central	135	2,391
South Central	92	1,218
West	122	1,413
Other	4	37
Total	534	7,684

SOURCE: National Perinatal Information Center, unpublished data from the American Hospital Association's 1983 Annual Survey of Hospitals, Providence, RI, December 1986.

Laboratories' inventory of military hospitals and all special care units for newborns. It is also likely that the National Perinatal Information Center underestimates the number of Level II units, but the magnitude of the difference is still unexplained.

The actual number of Level 111 units, fully staffed by neonatologists and capable of providing the most sophisticated prolonged life support, is probably close to *420*. About 485 hospitals reported that they had NICUs in **1983 on the American Hospital Association's Annual Survey of Hospitals, but further investigation by the National Perinatal Information Center refined that figure to about 420 (144). Through interviews with maternal and child health officials and other experts in the field, some hospitals were dropped from the list** while others were added.

Even Level III hospitals have varying capabilities. Forty children's hospitals have NICUs. These children's hospitals, along with many university hospitals, tend to provide the most sophisticated neonatal intensive care, often in conjunction with specialized pediatric surgery, Neonatologists sometimes refer to these centers as Level IV hospitals.

UTILIZATION

Again reflecting data from Level II and Level 111 units combined, table 2 shows that infants spent over 2 million days in NICUs in 1983, maintaining an average NICU occupancy rate of 73 percent. There was considerable variation in occupancy by geographic area, with the North Central region reporting only a 65-percent occupancy rate and the Northeast and the Western regions each reporting an 80-percent occupancy rate. As the national occupancy rate for all hospital beds

Table 2.—Neonatal Intensive Care Unit Days of Care and Occupancy in the United States, 1983

Region	Patient days	Occupancy (percent)
Northeast	471,395	80
South Alantic	277,582	76
North Central	569,545	65
South Central	300,771	68
West	411,961	80
Other	8,468	63
Total	2,039,722	73

SOURCE National Perinatal Information Center, unpublished data from the American Hospital Association's 1983 Annual Survey of Hospitals, Providence, RI December 1986

was 76 percent in 1983, the widely expressed concern that NICU beds are filled to overcapacity was not substantiated by these data (5). Of course, the experience of individual neonatal intensive care units varies widely, and some NICUs do report regular over-utilization (47,143).

The number of admissions to NICUs, and therefore the average length of stay, is not available from national databases. Based on total patient days and average lengths of stay reported by several groups of Level III centers (see table 3), OTA estimates that between 150,000 and 200,000 infants are admitted annually to neonatal intensive care units, or between *4* to *6* percent of all newborns.

Between *50* and 80 percent of all admissions to NICUs are low birthweight infants; there is considerable variation across centers (110,130,186). While the proportion of infants born weighing between 1500 and 2500 grams has decreased somewhat relative to total births over the last 10 years (currently 5.5 percent of all births), the proportion of very low birthweight infants has increased slightly (170). About 39,000 very low weight infants are born annually (a little more than 1 percent of all births), and virtually all of them require neonatal intensive care. In 1984, almost 17,000 of the very low birthweight infants weighed less than 1000 grams at birth.

Individual Level III centers report a trend toward increasing admissions of infants weighing under 1000 grams. Whereas these extremely low birthweight infants may have constituted 5 or 6 percent of admissions in the 1970s, in the 1980s they represented 10 to 12 percent and even 29 percent of all admissions to the NICU (48,87, 126,129,186). At least one report also documents a shift in the distribution of birthweights within the under 1000-gram birthweight group. From 1974 to 1983 at the University of Alabama in Birmingham, the proportion of admissions in the 501- to 700-gram category nearly doubled while the proportion of admissions in the 901- to 1000-gram group decreased (57).

Information on length of stay by birthweight category is shown in table 3. The average length of stay in *1984* for all sick newborns in those

Table 3.–Length of Stay by Birthweight Group, 1984

Birthweight (grams)	Average length of stay (days): Maryland Level III hospitals	Children's hospitals	San Francisco Level III hospitals
< 750	39.2	57.7	40.8
751-1000	65.3	59.1	56.3
1001-1500	46,4	45.4	41.2
1501-2000	21.1	25.0	17.9
2001-2500	7,8	16.6	10.0
>2500	4,4	11.3	8.4
Total < 1500	49.1	50.4	44.9
Total < 2500	23,8	31.6	29.5
Total all infants	10.3	17.1	18.8

[a]In Maryland's seven hospitals with Level III Neonatal Intensive Care Units (N ICUs), includes all newborns who fall into the major diagnostic category (M DC) for neonates, MDC 15, excluding normal newborns.
[b]In a sample of 13 children's hospitals. includes all neonates admitted under age 28 days, except normal newborns and infants who died or were transferred within 24 hours of birth The latter are included in the total for all Infants
[c]In two San Francisco hospitals with Level III NICUs includes all infants admitted to the NICUs

SOURCES Information Service Center, Inc Baltimore, MD, unpublished data, prepared under contract with the Of fice of Technology Assessment July 1986, N ational Association of Children Hospitals and Related Institutions, Inc , Alexandria VA, unpublished data, August 1986 and C S Phibbs, University of Call fornia, San Diego, unpublished data, March 1987 centers reporting data ranged from 10 to 19 days while the average length of stay for very low birthweight infants ranged from 45 to 50 days. As expected, the length of hospital stay increases as birthweight decreases. For extremely low birthweight infants under 1000 grams who survive to hospital discharge, it takes at least 70 to 90 days in the hospital to reach the necessary size and maturity so that continuous professional nursing care is no long required (see table 5). The implications of other risk factors for length of stay are discussed n the following section on costs.

COST

Neonatal intensive care is expensive, ranking among the most costly of all hospital care.[2] Average hospital costs for low birthweight babies in 1984 ranged from $11,670 to $39,420 (see table 4).[3] Among 10 diagnoses studied by Showstack and his colleagues, infants with respiratory distress syndrome (a major problem among premature, low weight babies) had substantially higher hospital charges than any other group, including patients with acute myocardial infarction or kidney transplantation (154). The costs for the sickest and tiniest infants in neonatal intensive care rank with the most expensive medical procedures that are performed today, like cardiac or bone marrow transplantation (96,145).

The distribution of costs among patients in the neonatal care nursery is highly skewed. A significant portion of the variation among infants in

‘The costs for physicians’ services in NICUs are not reflected in this section because data on physician charges were unavailable. Estimates vary, but physicians’ charges probably raise overall medical care charges by about 15 percent (79,128). Typically, neonatologists charge a daily visit fee for each patient in the NICU and additionally bill all procedures, such as catheterization, separately. Other consulting physicians also charge for their services. With the extremely long hospital stays of most very low birthweight infants, physicians’ charges can become a substantial liability for patients’ families.

‘The three data sources in tables 4 and 5 show such a wide range in hospital costs in part because they report on different populations. The data from the Maryland and children’s hospitals include all newborns who are hospitalized (except normal newborns), while the data from the San Francisco hospitals include only NICU admissions. Because the majority of the larger low birthweight infants (those with birthweights between 1500 grams and 2500 grams) do not require intensive care, the cost data for these birthweight categories, although reflecting average hospital costs, underestimate NICU costs. Box A provides a full explanation of the databases and their limitations.

Table 4.—Hospital Cost by Birthweight Group, 1984

Birthweight (grams)	Average hospital costs: Maryland Level III hospitals	Children’s hospitals	San Francisco Level III hospitals
< 750	$25,069	$48,773	$58,053
751-1000	38,750	47,068	76,387
1001-1500	22,266	32,530	53,663
1501-2000	8,594	16,370	20,845
2001-2500	2,898	13,794	16,751
>2500	1,202	9,358	14,601
Total < 1500	26,737	38,171	60,015
Total < 2500	11,666	23,639	39,421
Total all infants	4,411	13,416	26,946

[a] In Maryland’s seven hospitals with Level III Neonatal Intensive Care Units (NICUs), includes all newborns who fall into the major diagnostic category (MDC) for neonates, MDC 15, excluding normal newborns. Charges are converted to costs through a weighted cost-to-charge ratio derived from the Maryland Health Services Cost Review Commission’s ratios for individual hospitals and their relative contribution to total births.

[b] In a sample of 13 children’s hospitals, includes all neonates admitted under age 28 days, except normal newborns and infants who died or were transferred within 24 hours of birth (The latter are included in the total for all infants.) Costs are derived from a cost finding methodology employed by National Association of Children’s Hospitals and Related Institutions and adjusted for labor differentials.

[c] In two San Francisco hospitals with Level III NICUs, includes all infants admitted to the NICUs. Charges are adjusted to costs using Medicaid’s cost-to-charge ratio.

SOURCES: Information Service Center, Inc., Baltimore, MD, unpublished data, prepared under contract with the Office of Technology Assessment, July 1988; National Association of Children’s Hospitals and Related Institutions, Inc., Alexandria, VA, unpublished data, August 1988; and C.S. Phibbs, University of California, San Diego, unpublished data, March 1987.

Box A.—How To Interpret the Data in Tables 3, 4, and 5

Tables 4 and 5 show such a wide range of costs because the three data sources that are cited report on somewhat different populations. The seven Level III hospitals in Maryland have the lowest costs. These data include all infants born in the hospitals who are assigned to the diagnosis-related groups (DRGs) for neonates (excluding normal newborns). Because of inconsistencies in coding, these data may include some infants older than **28** days who return to the hospital for routine surgical corrections of congenital anomalies and may exclude some seriously ill newborns who are assigned to non-neonate DRGs that describe the organ system involved with their problems (109). Any newborn weighing less than 2500 grams is included in this classification because of his low birthweight, regardless of the extent of medical problems. Thus especially in the heavier low birthweight groups, the Maryland data underestimate NICU costs because many of the babies, though hospitalized, are not sick enough to warrant intensive care.

Conversely, the other 2 data sources, 13 children's hospitals and 2 university-affiliated San Francisco hospitals, tend to overestimate average NICU costs. Most children's hospitals do not have obstetrical services, and they typically serve as super-referral centers for the most difficult and complicated cases, often those requiring complex surgery. They, along with many university hospitals, are sometimes referred to as Level IV facilities because their caseloads require such intensive care. These data sources reflect average costs for the sickest infants.

There are several additional caveats about these data. The data from the children's hospitals include all admissions of infants under 28 days of age, but like the Maryland data, it is not known which infants actually received care in the intensive care unit. For example, very complicated surgical patients with congenital problems often are placed in pediatric intensive care units instead of NICUs even if they are newborns. And because children's hospitals are almost exclusively referral *centers,* many of the babies return to their original hospitals after surgery or to complete recuperation. Such transfer policies underestimate true lengths of stay and concomitant costs for these newborns.

The two San Francisco hospitals constitute the only data source that reports only on infants admitted to the NICU. Thus it is the best source of information on the cost experience of the heavier birthweight infants (over 1500 grams) in NICUs. However because one of these hospitals is also a surgical center for infants with congenital anomalies, these data may overestimate typical NICU costs for the larger infants. Moreover, the same hospital has an aggressive program for back-referring infants to their originating hospitals which explains, in part, the generally shorter lengths of stay reported by the San Francisco hospitals compared with the children's and Maryland hospitals. Finally this database is limited by the size of the population. The San Francisco hospitals had a total caseload of 580 infants while the Maryland hospitals and the children's hospitals each report on over 5,000 infants. There were 290 low birthweight infants in the San Francisco hospitals. The Maryland hospitals had 1,540 infants and the children's hospitals had 2,240 infants in their low birthweight populations.

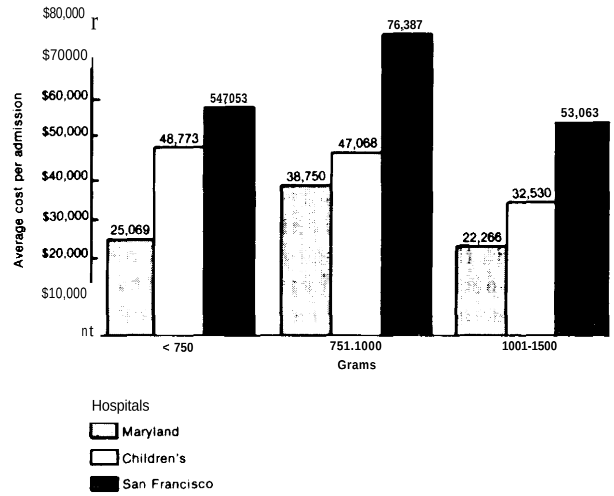
cost and length of stay is explained by four measures of risk: birthweight, survival to hospital discharge, assisted ventilation, and surgical intervention (109,13 o). A study on costs in 13 children's hospitals conducted by the National Association of Children's Hospitals and Related Institutions in 1984 found that these factors explained 45 percent of the variation in costs among neonatal cases when the extreme outliers were removed from the calculation (111). A different study of admissions to six Level 111 NICUs in California found 42 percent of the variation in costs was explained by these factors plus two others: multiple births and discharge to another hospital (130).

Birthweight has the greatest explanatory power. Costs increase as birthweight falls. The average hospital costs for very low birthweight babies range from $26,740 to $60,015. (See table 4.) Infants in the 750- to 1000-gram birthweight group, which uses resources very intensively, have average costs between $38,750 and $76,390. The average hospital costs for infants with birthweights below 750 grams are lower than the average costs for those infants in the 750- to 1000-gram group because so many of the tiniest babies die within a short time of birth, thus incurring fewer expenses (figure 1).

If only survivors are counted, costs increase across birthweight groups. (See table 5.) Because of the high mortality experienced at the lowest birthweights, survival to discharge is the most important factor in explaining variations in costs for infants with birthweights under 1500 grams. A large percentage of these premature newborns die within a very short time after birth and consume minimal resources. Another substantial portion of the infants live past the first critical 24 to 72 hours and consume considerable resources, but eventually die. The children's hospital data indicate that even if only this latter group, infants who use resources intensively but ultimately die, is considered, on average survivors are still more expensive (109). As expected, the tiniest infants who survive, those with birthweights from 500 to 750 grams, have the highest costs and hospital stays, from $61,700 to $149,180 and from 87 to 109 days respectively.

Table 6 shows costs and lengths of stay for newborns who require assisted ventilation for more than 72 hours. Unfortunately, virtually all infants born weighing under 750 grams and most infants in the 750- to 1000-gram birthweight group do require prolonged respiratory assistance. Only 15 percent of the under 1000 gram survivors shown in table **6** did not require assisted ventilation. The average costs of these nonventilated extremely low

Figure 1.— Hospital Cost by Birthweight Group, 1984



SOURCE: Office of Technology Assessment (see table 4), 1987.

birthweight survivors are only a third of the *$63,750* required to care for the infants on assisted ventilation. For all low birthweight babies, average hospital costs increase almost fourfold, from $11,470 to $40,550, if assisted ventilation is required. The use of assisted ventilation over 72 hours explains between 20 and 36 percent of the variation in costs among infants who weigh less than 1500 grams (109). For the heavier low birthweight babies, those in the **1500- to 2500-gram group, the most important explanatory factor is whether surgery is required. About 12 percent of the variation** in costs among cases is explained by surgical intervention (109).

Table 5.—Hospital Cost and Length of Stay Per Very Low Birthweight Survivor, 1984

	Maryland Level III hospitals		San Francisco children's hospitals		Level III hospitals	
Birthweight (grams)	ALOS[d]	Mean $	ALOS[d]	Mean $	ALOS[d]	Mean $
> 750	97.9	$61,706	87.4	$67,892	108.5	$149,184
751-1000	86.2	48,290	71.4	54,805	66.4	88,028
1001 -1500	48.5	21,848	47.3	32,168	44.8	56,276
Total	61.5	31,426	56.3	40,514	55.1	71,417

[a]In Maryland's seven hospitals with Level III NICUs, includes all newborns who fall into the major diagnostic category (MDC) for neonates, MDC 15, excluding normal newborns

[b]In a sample of 13 children's hospitals includes all neonates admitted under age 28 days, excePt normal newborns.

[c]In two San Francisco hospitals with Level III NICUs, includes all infants admitted to the NICUs.

[d]ALOS denotes average length of stay (days).

SOURCES Information Service Center, Inc., Baltimore, MD, unpublished data, prepared under contract with the Office of Technology Assessment, July 1986; National Association of Children's Hospitals and Related Institutions, Inc., Alexandria, VA, unpublished data, August 1986, and C.S. Phibbs, University of California, San Diego, unpublished data, March 1987

Table 6.—Hospital Cost and Length of Stay for Newborns[a] Requiring Assisted Ventilation, 1984

	Assisted ventilation		No assisted ventilation	
Birthweight (grams)	Mean $	ALOS[c]	Mean $	ALOS[c]
< 1000	$63,753	79,2	$22,694	50.5
1001-1500	40,055	53.9	17,732	35.2
1501-2000	47,951	49.6	11,364	23.1
2001-2500	23,233	23.2	8,709	13.0
>2500	29,112	27.7	5,383	8.0
Total < 1500	49,295	63.8	18,559	37.8
Total < 2500	40,548	49.4	11,474	20.4
Total all infants	35,322	39.5	6.555	10.4

[a]Data excludes normal newborns, Infants transferred to another hospital within 4 days of birth, and all infants who died before discharge
[b]Infants required mechanical ventilation forover3 days
[c]ALOS denotes average length of stay (days)

SOURCE National Association of Children's Hospitals and Related Institutions, Inc., Alexandra. VA, unpublished data, August 1986

More of the increase in the costs of neonatal intensive care over time is due to a sicker case mix than to the use of more services or general inflation. In comparing admissions to the NICU at the University of California, San Francisco between 1976-78 and 1983-84, Phibbs and his colleagues found that mean charges increased from $6,230 to $25,230. The cost to treat similar types of cases increased **30 percent, and this change was attributed to technology and higher prices. Inflation accounted for another 23 percent, and the remaining 47-percent increase** in overall charges was attributed to a change in the kinds and severity of cases (94). The caseload in this Level III nursery became much more concentrated with extremely low birthweight infants and with infants who required complex surgery than in earlier years. The researchers hypothesized that the sicker case mix was caused by increased regionalization and greater availability of Level II beds (94).

Other researchers in the same institution followed the hospital course of infants with respiratory distress syndrome as part of a larger study of costs and changes in clinical practice. They found that between 1972 and 1982 resource use increased more for infants with respiratory distress syndrome than for any of the other nine diagnoses studied. They concluded that these newborns received increasing quantities of services over the decade and that the most difficult costs to contain are those for such critically ill patients (154).

Chapter 3

Effectiveness of Neonatal Intensive Care

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INTRODUCTION

The remarkable decline in infant and neonatal mortality in this country since 1960 is chronicled in the OTA assessment, *Healthy Children: Investing in the Future (170).* Neonatal mortality rates (deaths during the first 28 days of life per 1000 live births) are affected by both birthweight distribution and birthweight-specific mortality rates. Assuming that better neonatal and obstetrical care imply improved outcomes for infants at a given birthweight while shifts in birthweight distribution toward heavier babies can be attributed to improved prenatal care and maternal health and nutrition, the concern in this case study is the direction of the birthweight-specific mortality rates.

Improvements in the birthweight-specific mortality rates accounted for 91 percent of the overall decline in neonatal mortality between 1960 and 1980 (27). Moreover, two-thirds of the decline in birthweight-specific neonatal mortality resulted from improved survival of low birthweight infants. Decreases in the mortality rates of infants weighing between 1500 and 2500 grams contributed more than any other weight group, including the very low birthweight group, because of both greater proportional decreases and higher absolute declines in mortality (184). In reviewing perinatal mortality rates by birthweight between 1960 and 1977 in California, Williams and Chen concluded that much of the decline could be attributed to the advent of neonatal intensive care (as well as the increased rate of cesarean section) (184).

The effectiveness of neonatal intensive care must be measured not only by whether more lives are being saved but also by whether the long-term health outcome for the babies and their families is good. The health status of survivors, specifically the rate of serious disability or handicap, has been the subject of intense interest. For the larger low birthweight infants, those with birthweights between 1500 and 2500 grams, neonatal intensive care has been accepted as a mature and effective technology (25,166). But because the risk of handicap increases with decreasing birthweight, debate continues about providing universal care for all very low birthweight infants (151,25).

This chapter focuses on changes in mortality and morbidity over the past 25 years for such very low birthweight infants. Following discussions of mortality and handicap rates, the three leading causes of mortality and morbidity in the neonatal intensive care unit (NICU) are examined in detail: respiratory distress syndrome, intraventricular hemorrhage, and retinopathy of prematurity. These clinical problems not only account for the majority of deaths among very low birthweight infants, but they can also lead to substantial long-term disabilities. The outlook for technological advances in these areas is also discussed.

MORTALITY RATES

Birthweight-specific death rates on a national basis are not available for trend analysis because not all States routinely link birth certificates (where birthweight is noted) with death certificates. However, many individual Level III centers report their experiences in the medical literature. Because the mortality rates for infants born in the Level III hospitals are lower than the mortality rates for infants who do not have immediate access to care in the intensive care units (see ch. 5), these institutional reports may be the best indicator of the impact of NICUs on mortality outcomes.

There are problems, however, in comparing mortality results from one hospital to another because of differences in the demographic charac-

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teristics of the populations served, in the standards of care, in the proportions of high-risk pregnancies, and in the selective application or withdrawal of intensive treatment measures **(83). Displaying the data by birthweight group does not completely control for these differences. For example, the distribution of gestational age within** a given birthweight group is probably the most important indicator of survival. Moreover, individual nurseries typically report on only small numbers of infants, and mortality rates may fluctuate from year to year. Bearing in mind these caveats, OTA reports and combines institutional data to permit generalization about mortality rates over time.

Table 7 summarizes reports on mortality for very low birthweight infants born in Level III hospitals (inborn) during the past 10 years. Table 8 is a similar compilation, but it lists studies that report on admissions to NICUs (inborns and transfers). The two kinds of denominator populations are reported separately for several reasons. On the one hand, inborn populations would be expected to have higher mortality rates because of the high proportion of infants who die almost immediately in the delivery room and are never admitted to the NICU. On the other hand, while the infants admitted to the NICU have survived through the first critical minutes or hours of life, the infants born in other hospitals (transfers) may be selectively sicker because of the period of time that they were denied intensive care before and during transport. A study in New York City on the effect of place of birth on mortality in fact supports both these conclusions which are further discussed in chapter 5 of this case study (119). In OTA's literature review, inborn populations had significantly lower pooled mortality rates (for 1980 to 1985) than NICU populations in the 750- to 1000-gram and the 1001- to 1500-gram birthweight groups. The differences between the two kinds of nursery populations were not statistically significant in the smallest babies born weighing under **750 grams.**

With one exception, there has been steady and statistically significant improvement in mortality rates among very low birthweight infants throughout the last 10 years. In 1985, a baby born with a birthweight between 1001 and 1500 grams has a 90 percent chance of surviving. The most substantial improvement of the 1980s over the late 1970s, in neonatal mortality rates is in the 751- to 1000-gram birthweight group where today's infants have about a 70 percent chance of surviving if they are admitted to an NICU.

The exception to the mortality decline over the past decade is among the tiniest inborn babies, those in the under 750 gram group, where some extremely promising, but mostly variable, results are reported on babies born in the 1980s.[1] For this birthweight group, Columbia University reports only 28 percent of their inborn infants died in 1986 and the University of Missouri-Kansas City School of Medicine shows only a 53 percent neonatal mortality rate in **1983 and 1984 (46,80). However, other institutions which report their experiences in the 1980s show much worse mortality rates. The 1980-85 pooled results for both denominator populations show that about two-thirds of this birthweight group dies.** Such wide variation among centers may mean that the technology of neonatal intensive care is continuing to change rapidly.

Table 9 shows the great progress that medicine has made over the past several decades in reducing birthweight-specific mortality rates among very low birthweight infants.[2] The pooled institutional results on mortality from 1961 through 1975 are taken from an earlier OTA literature review (25). Mortality for infants with birthweights of 1001 to 1500 grams has fallen from more than 50 percent in 1961 to only 10 percent today. And whereas more than 90 percent of all infants weighing under 1000 grams died in 1961, the inborn ne-

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1 Even for this birthweight subgroup (under 750 grams), the pooled mortality rates calculated for NICU populations decreased significantly from 1975-80 to 1980-85.

2 It should be noted that improvements in the birthweight-specific mortality rates may also be attributable to factors other than solely neonatal intensive care. For example, healthier cohorts of low birthweight infants may be delivered through selective abortion, better obstetrical techniques, improved maternal care and nutrition, and so forth (18). It is not possible to sort through each factor's relative contribution, but clearly neonatal intensive care is very important.

Table 7.—Comparative Neonatal Mortality for Very Low Birthweight Infants Born in Level Ill Hospitals, 1975-85

		Birthweight (grams)							
		501-750[a]		751 -1000[a]		< 1000		1001-1 500[a]	
Reference[b]	Year of birth	Deaths/births	Percent	Deaths/births	Percent	Deaths/births	Percent	Deaths/births	Percent
Knobloch (83)	1975-79	—	—	50/74	68 "/0		—	61/21 1	290/o
KOOPS (85)	1974-80	60/82	73 "/0	49/108	45 "/0	109/1 90	57 "/0	58/348	17"/0
Phibbs (129)[c]	1976-78	—	—	—		18/35	51 "/0	10/82	12"/0
Kitchen (82)[c]	1977-78	47/62[d]	760/o	30/65	[d]460/o	771127	61 o/o	33/250	13"/0
Nelson (1 13).	1977-78	—		.	—	220/360	61%	1221720	17"/0
Buckwald (24)[c].	1977-81	50/90	[d]560/o	—	—	—	—	—	—
Hoskins (71).	1979-80	20/39	51 "/0	14167	21 "/0	34/106	320/o	—	—
Pooled subtotal	1975-80	1771273	65%	143/314	460/o	458/818	560/o	284/1,611	180/0
Brans (22)	1978-82	68177	880/0	49/105	480/o	117/182	640/o	411236	17"/0
Avery (6)[c].	1983	31/50d	62%	71/46[d]	15"/0	38/96	40 "/0	13/109	12 "/0
Kilbride (80)	1983-84	46/87[d]	53 "/0	—		—	—	—	—
Horbar (69)[e].	1983-84	—		88/357	[d]250/o	—	—	101/1,243	80/0
Hack (61)[c].	1982-85	57/77	74%	24173	33 "/0	81/150	54 "/0	30/216	14 "/0
Driscoll (46)[c].	1986	5/18[d]	280/o	2/21[d]	10 "/0	7/39	180/0	1/75	1%
Pooled subtotal	1980-85	2071309	670/o	1701602	280/o	2431467	520/o	186/1 ,879	10%

[a]Some studies reported birthweight categories as 500 to 749, 750 to 999, and 1000 to 1499 9
[b]See references in the back of this case study for full citations.
[c]Deaths reported to hospital discharge.
[d]Includes birthweight categories 501 to 800 g and 801 to 1000 g
e Report on multiple neonatal intensive care centers.

SOURCE: Off Ice of Technology Assessment, 1987

Table 8.—Comparative Neonatal Mortality in Neonatal Intensive Care Units for Very Low Birthweight Infants, 1975-85

		Birthweight (grams)							
		501-750[a]		751-1000[a]		≤1000		1001	
Reference[b]	Year of birth	Deaths/ admissions	Percent	Deaths/ admissions	Percent	Deaths/ admissions	Percent	Deaths/ admissions	Percent
Hack (62)	1976-78	35/44	80%	52/119	44%	87/163	53%	58/304	19%
Schechner (142)	1976-78	18/18	100%	14/28	50%	32/46	70%	14/103	14%
Britton (23)[c]	1974-77	75/90	83%	—	—	—	—	—	—
Hirata (68)	1975-80	32/60	53%						—
Philip (131)[c]	1976-79	37/48	77%	54/98	55%	91/146	62%	58/342	7%
Marlow (99)[c]	1976-80	43/46	93%	74/117	63%	117/163	72%	124/350	35%
Sell (146)[d]	1978	449/567	79%	403/813	50%	852/1,380	62%		
Bennett (13)	1977-80	76/95[e]	80%	—	—	—	—	—	—
Cohen (32,33)	1977-80	39/54	72%	33/118	28%	72/172	42%	—	—
Orgill/Yu (118,188)	1977-80	15/26	58%	32/81	40%	47/107	44%	41/280	15%
Walker (180)	1977-81	112/132[e]	85%	57/115[e]	50%	69/247	68%	—	—
Vohr (176)[c]	1978-80							39/287	14%
Stahlman (159)	1977-81	90/133[e]	68%	70/187[e]	37%	160/320	50%	—	—
Pooled subtotal	1975-80	1,021/1,313	78%	789/1,676	47%	1,627/2,744	59%	334/1,666	20%
Levi (92)	1978-81	59/71[e]	83%	—	—				
Stewart (161)	1979-84	37/59	63%	41/136	30%	78/195	40%	37/277	13%
Sell (146)[d]	1983	511/800	64%	368/1,085	34%	879/1,885	47%		—
Sandhu (141)	1983	15/20[e]	75%	14/38[e]	37%	29/58	50%	—	—
Phibbs (126)[c]	1983-84	14/22	64%	6/36	17%	20/58	34%	12/86	14%
Davidson (38)[c]	1983-84	33/44	75%	25/61	41%	58/105	55%	19/147	13%
Kraybill (86)[c,d]	1984	109/149	73%	78/237	33%	187/386	48%	72/613	12%
Nichols (115)[c]	1985	21/32[e]	66%	5/9[e]	56%	26/41	63%	—	—
Pooled subtotal	1980-85	799/1,197	67%	537/1,602	34%	1,277/2,728	47%	140/1,123	12%

[a]Some studies reported birthweight categories as 500 to 749, 750 to 999, and 1000 to 1499 g.
[b]See references in the back of this case study for full citations.
[c]Deaths reported to hospital discharge.
[d]Report on multiple neonatal intensive care centers.
[e]Includes birthweight categories 501 to 800 g and 801 to 1000 g

Office of Technology Assessment, 1987.

Table 9.—inborn Neonatal Mortality Rates for Very Low Birthweight Infants, Pooled Institutional Data

	Birthweight (grams)			
	< 1000		1001-1500	
Year of birth	Deaths/births	Rate[a]	Deaths/births	Rate[a]
1961-65	1851197	939	1421274	518
1966-70	381/443	860[b]	2121567	374[b]
1971-75	209/274	763[b]	541253	213b
1976-80 ., ...	4581818	560[b]	284/1,611	176
1981-85	2431467	520	186/1,879	99[b]

[a]Rate deaths/1,000 live births
[b]Significantly d! fferent from preceding 5-year rate (P <0 01)

SOURCES For years 1976.85, Off Ice of Technology Assessment (see table 7) For years 1961.75, P Budetti, P McManus N Barrand et al , The Costs *and Effectiveness of Neonatal Intensive Care* (Health Technology Case Study #10), prepared for the Off Ice of Technology Assessment, U S Congress, OTA. BP-H-9 (Springfield, VA: National Technical Information Services, August 1981)

onatal mortality rate now is about 52 percent.[3] This achievement reflects improvements primarily in the 750- to 1000-gram birthweight group since mortality is still very high in the smallest and most premature infants, those under 750 grams. Neonatologists are justifiably proud of breaking the 1000 gram barrier, and they look now to infants weighing under 800 grams as their great challenge.

‘The true neonatal mortality rate today for newborns weighing under 1000 grams who have access to neonatal intensive care is probably closer to 47 percent, the rate shown in table 8 for NICU populations. OTA used the 52 percent rate (from table 7 for inborn populations with birthweights under 1000 grams) in table 9 to be consistent across time and denominator populations. Several of the studies in table 7 showing the best survival rates for inborn populations did not report on all infants with birthweights between 500 and 1000 grams. The results of these studies could not be included in the pooled total for infants with birthweights under 1000 grams, and thus the 52 percent rate probably overestimates mortality,

HANDICAP RATES

When neonatal intensive care was introduced, concern was expressed that many sick and premature infants, who otherwise would have died, would be saved and result in a large number of handicapped children. Early, well-publicized studies of very low birthweight babies born in the 1940s and early 1950s, long before the era of neonatal intensive care, fueled this concern because they showed very high rates **(30 to 40 percent) of cerebral palsy and other forms of impairment** in survivors (45,95). Two groups, Budetti and his colleagues in their earlier OTA assessment of neonatal intensive care and a team of British researchers, independently attempted to resolve this question by reviewing published reports from hospital nurseries that described outcomes for very low birthweight infants who were born after 1945. Both review articles found that the handicap rate from the very early period dropped sharply by the mid-1960s (possibly before neonatal intensive care was widely introduced). Furthermore, from the mid-1960s through about 1977, the proportion of very low birthweight survivors with serious handicaps remained stable and relatively low (about 14 percent of survivors or from 6 to 8 percent of live births) (25,162).

These reviews were reassuring in that the introduction of neonatal intensive care apparently had not increased the proportion of survivors who are seriously handicapped. However, the two reviews covered mortality outcomes only for infants born before **1977. At that time, no published data were available on outcomes for infants with birth**weights below 800 grams, perhaps because so few such infants survived. Moreover, mortality rates have continued to drop significantly over the last 10 years for all birthweight groups under 1500 grams, and the possibility exists that infants, who previously would have succumbed because of their problems, are now rescued through new technology and contribute to the incidence of survivors with neurological damage. To determine whether handicap rates have changed during the late 1970s and the 1980s, OTA reviewed the literature for reports on morbidity outcomes for infants born between 1975 and 1985. The results are shown in tables 10 through 12 by birthweight group.

Like birthweight-specific mortality data, birthweight-specific morbidity data are not collected on a routine basis in the United States. Thus reports from individual nurseries are the only available data source that reflects the long-term morbidity of very low birthweight infants. All of the shortcomings discussed previously for the institutional data on mortality hold as well in using and pooling morbidity data from individual nurseries. Differences in the character and experiences of the study populations yield different results. Moreover, comparisons of morbidity are further complicated by the different ways in which outcome is measured and reported. There are differences in the definitions of abnormalities, in the details with which diagnostic categories are specified, in the ages at which followup examinations are done, and in the measures used in the neurodevelopmental evaluations (78,83).

The interrelationship of mortality and morbidity is especially difficult to interpret. It is likely that neonatologists' attitudes and decisions concerning termination of life support for very low birthweight infants who manifest severe neurological dysfunction are a major factor in determining the rate of serious morbidity among survivors. Thus, a comparatively high neonatal mortality rate might be expected to be associated with a relatively low rate of handicap. Although several reports on the under 800-gram population fit this hypothesis (13,60,61), just as many studies reported relatively high survival and low handicap rates (68, 79,80, 161). Overall OTA found no consistent relationship between mortality and the rate of serious morbidity in its literature review,

Determinations of long-term morbidity and disability cannot be made at hospital discharge. The extent to which researchers were able to follow NICU survivors through the first few years of life and classify their disabilities varied from study to study. In general, followup rates were highest in the studies reporting on the smallest birthweight infants. This is because the tiniest babies are less numerous and tend to have problems that encourage their families to seek ongoing medical care. Conversely, a larger percentage of the NICU survivors with birthweights between 1000 and 1500 grams were lost to followup, but many of these infants are normal. In all three birthweight groups examined by OTA, a substantial portion of the infants lost to followup died during the postneonatal period. Although many of the deaths were directly related to complications of prematurity and intensive care treatment, sudden infant death syndrome (SIDS) was also a major cause of death after hospital discharge. The high postneonatal mortality rate experienced by very low birthweight infants, perhaps 10 to 15 times that found among normal birthweight infants, is not well understood by medical researchers (170,188).

OTA adopted the definitions of handicap used by the reviewers in the earlier OTA assessment in order to categorize disparate reports. "Serious handicaps" are defined as: severe mental retardation (IQ or developmental quotient below 70); cerebral palsy of significant degree (spastic diplegia, paraplegia, tetraplegia, hemiplegia); major seizure disorders; blindness; and severe hearing defects (25). "Moderate handicaps" are narrowly defined to include all infants with a developmental quotient or IQ between 70 and 80. No attempt was made in this review to capture the "mild" impairments that many very low birthweight infants develop later in early childhood or even at school age because most published reports follow NICU survivors only to 2 or 3 years of age (68). It should be noted that there is a higher incidence of such relatively mild handicaps, which include behavioral, learning, and language disorders, in very low birthweight infants than in normal birthweight children (116).

The incidence of serious handicap increases significantly with decreasing birthweight (tables 10 to 12). For infants born between 1975 and 1985, OTA found that 26 percent of surviving infants with birthweights below 800 grams, 17 percent

Table 10.—Handicap Rates in Infants With Birthweights Under 800 Grams, 1975-85

		Infants surviving to hospital discharge		Survivors followed after hospital discharge: Total		Children with serious handicaps[a]		Children with serious or moderate handicaps[b]	
Reference[c]	Year of birth	Number	Percent	Number	Percent[d]	Number	Percent[e]	Number	Percent[e]
Saigal (139)[f]	1973-78	5[g]	(10%)	4	(80%)	1	(25%)	2	(50%)
Britton (23)	1974-77	39	(25%)	37	(95%)	8	(22%)	18	(49%)
Hirata (68)[f]	1975-77	24	(40%)	18	(75%)	3	(17%)	6	(33%)
Marlow (99)[f]	1976-80	3	(7%)	3	(100%)	1	(33%)	NA	—
Bennett (13)	1977-80	19	(20%)	16	(84%)	2	(13%)	4	(25%)
Cohen (32)[f]	1977-80	12	(28%)	9	(75%)	3	(33%)	3	(33%)
Saigal (140)	1977-80	41[g]	(29%)	38	(93%)	13	(34%)	20	(53%)
Orgill (118)[f]	1977-80	11	(42%)	11	(100%)	3	(27%)	3	(27%)
Walker (180)	1977-81	20	(15%)	20	(100%)	6	(30%)	8	(40%)
Buckwald (24)	1977-81	65	(45%)	54	(83%)	19	(35%)	31	(57%)
Kraybill (87)	1980	4	(24%)	4	(100%)	1	(25%)	1	(25%)
Levi (92)	1978-81	12	(17%)	10	(83%)	2	(20%)	2	(20%)
Stewart (161)	1979-83	16[h]	(27%)	12	(75%)	2	(17%)	NA	—
Hack (60,61)[f]	1982-85	20	(26%)	18	(90%)	2	(11%)	4	(22%)
Pollara (132)[f]	1983-84	3	(8%)	2	(67%)	1	(50%)	1	(50%)
Kilbride (79,80)	1983-84	41	(47%)	34	(83%)	8	(24%)	11	(32%)
Pooled total	1975-85			290		75	(26%)	114	(41%)[i]

[a]Serious handicaps are defined as the following: severe mental retardation (IQ or developmental quotient below 70); cerebral palsy of significant degree; major seizure disorders; or blindness.
[b]Serious or moderate handicaps includes all those handicaps defined above as serious plus a developmental quotient or IQ between 70 and 80.
[c]See references in the back of this case study for full citations.
[d]Of those infants surviving to hospital discharge.
[e]Of survivors followed after hospital discharge.
[f]Includes infants with birthweights between 500 and 750 grams.
[g]Survival calculated on regional population of births.
[h]Survived to end of first year.
[i]Denominator population is 275 infants.

SOURCE: Office of Technology Assessment, 1987.

Table 11 .—Handicap Rates in Infants With Birthweights Between 750 and 1000 Grams, 1975-85

Reference [c]	Year of birth	Infants surviving to hospital discharge		Survivors followed after hospital discharge: Total		Children with serious handicaps		Children with serious or moderate handicaps	
		Number	Percent	Number	Percent [d]	Number	Percent [e]	Number	Percent [e]
Saigal (139)	1973-78	32[f]	(49%)	31	(97°/0)	4	(13%)	10	(32%)
Knobloch (83)	1975-78	—		9		5	(55%)	6	(67%)
Marlow (99)	1976-80	43	(37%)	40	(93%)	10	(250/o)	NA	—
Orgill (118)	1977-80	48	(59%)	48	(100%)	7	(15°/0)	10	(21 %)
Cohen (32)	1977-80	84	(720/o)	72	(86°/0)	4	(6°/0)	18	(25%)
Saigal (140)[g].	1977-80	76[f]	(67%)	72	(95°/0)	13	(18°/0)	35	(49%)
Walker (180)[g].	1977-81	58	(50%r)	48	(83°/0)	5	(10%)	10	(21%)
Kraybill (87)[g]	1980	26	(670/o)	25	(96°/0)	3	(12%)	7	(28%)
Stewart (161)	1979-83	73[h]	(54%)	54	(74%)	7	(13%)	NA	—
Pollara (132)	1983-84	44	(690/o)	35	(80°/0)	17	(49%)	NA	—
Pooled total	1975-84			434		75	(17%)	96	(31%)[i]

[a] Serious handicaps are defined as the following: severe mental retardation (IQ Or developmental quotient below 70); cerebral palsy of significant degree; major Seizure disorders, Or blindness
[b] Serious or moderate handicaps Includes all those handicaps defined above as serious PIUS a developmental quotient Or IQ between 70 and 80.
[c] See references in the back of this case study fOr full citations
[d] Of those infants surviving to hospital discharge
[e] Of survivors followed after hospital discharge.
[f] Survival calculated on regional population of births.
[g] Includes infants with birthweights between 500 and 800 grams
[h] Survived to end of first year.
I Denominator population is 305 infants.

SOURCE Office of Technology Assessment, 1987

Table 12.—Handicap Rates in Infants With Birthweights Between 1000 and 1500 Grams, 1975-85

		Infants surviving to hospital discharge		Survivors followed after hospital discharge: Total		Children with serious handicaps		Children with serious or moderate handicaps	
Reference[c]	Year of birth	Number	Percent	Number	Percent[d]	Number	Percent[e]	Number	Percent[e]
Hack (62)	1975-76	153	(76%)	128	(84%)	20	(16°/0)	NA	—
Saigal (139)	1973-78	147[f]	(83%)	131	(89%)	6	(5%)	26	(20%)
Knobloch (83)	1975-78	—		79		15	(19%)	28	(35%)
Sherman (152)	1976-77	34	(81%)	26	(76%)	NA		3	(12%)
Marlow (99)	1976-80	226	(65%)	210	(93%)	27	(13%)	NA	
Powell (133)	1979-81	285[f]	(73%)	276	(97%)	NA		31	(11%)
Stewart (161)	1979-83	227[g]	(82%)	168	(74%)	9	(5%)	NA	
Crombie (36)	1979-83	108	(82%)	77	(71%)	3	(4%)	5	(6%)
Pollara (132)	1983-84	165	(85%)	120	(73%)	20	(17°/0)	NA	—
Pooled total	1975-85			1,215		100	(11%)[h]	93	(16%)[i]

[a]Serious handicaps are defined as the following: severe mental retardation (IQ or developmental quotient below 70); cerebral palsy of significant degree, major seizure disorders; or blindness

[b]Serious or moderate handicaps includes all those handicaps defined above as serious plus a developmental quotient or IQ between 70 and 80

[c]See references in the back of this case study for full citations.

[d]Of those infants surviving to hospital discharge

[e]Of survivors followed after hospital discharge

[f]Survival calculated on regional population of births

[g]Survived to end of first year.

[h]Denominator population is 913 infants.

[i]Denominator population is 589 infants.

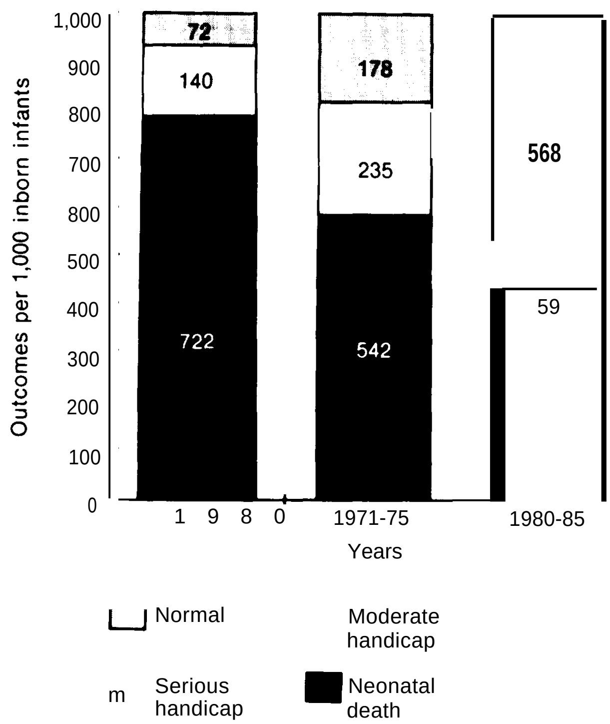
SOURCE Office of Technology Assessment, 1987 of survivors with birthweights between 750 and 1000 grams, and 11 percent of survivors with birthweights between 1000 and 1500 grams have major disabilities at 1 or 2 years of age. Of the surviving infants with birthweights under 800 grams, 41 percent have either a moderate or severe handicap, while only 16 percent of the survivors with birthweights between 1000 and 1500 grams are so handicapped.

These results corroborate the conclusions of Budetti and his coworkers (25). Within each birthweight group, the proportion of survivors with serious handicaps has not changed significantly since the mid-1960s. The earlier review did not report on infants with birthweights under 800 grams, so comparisons over time cannot be made for this birthweight group. The group of infants that was labeled in the earlier review as weighing less than 1000 grams almost exclusively included infants with birthweights between 750 and 1000 grams; the pooled rate of serious handicap for this birthweight category has not changed significantly from 1965-75 to 1975-85 (16 to 17 percent). Today, however, many more infants with birthweights below 800 grams are living and contributing both relatively more normal and handicapped children to the pool of survivors with birthweights under 1000 grams.

The conclusion that, within birthweight group, the rate of serious handicap among survivors has not changed significantly over time masks the contribution that neonatal intensive care probably has made to improved morbidity, as well as improved mortality, outcomes. Since many very sick babies who previously would have died are now surviving, *increasing* handicap levels **among survivors should be expected.** The finding of constant levels of handicap therefore points to the increasing effectiveness of neonatal intensive care for the long-term developmental outcomes for these children.

Figures 2 and 3 demonstrate graphically the effects of declining mortality on the relative proportions of normal and abnormal survivors.[4] The absolute numbers of both normal and seriously handicapped children increase. Infants with birthweights between 1000 and 1500 grams make up about 54 percent of all very low-weight births in the United States each year. Because of their relative numerical strength, the comparatively lower handicap rates of this "larger" infant group moderate the overall rates of disability among all very low birthweight infants. For example, with birth rates at the 1984 level, if today's neonatal intensive care was provided for all very low birthweight infants, about 2,200 seriously handicapped children would survive who would have died in 1975. This figure must be balanced against the 15,200 net increase in normal infants who would also survive under current conditions. The overwhelming majority of survivors in both the under 1500-gram and the under 1000-gram birthweight groups are normal.

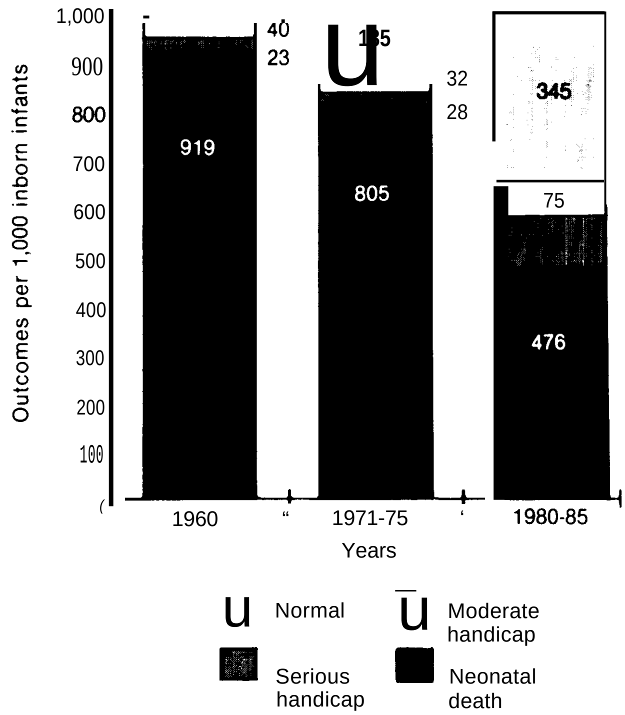
Figure 2.—Outcomes for Very Low Birthweight Infants (< 1500 gram) Born in Level III Hospitals, 1980-85



SOURCES: For years 1980-85, Office of Technology Assessment (see tables 7. 10, 11, and 12). For years 1980 and 1971-75, P. Budetti, P. McManus, N. Barrand, et al., *The Costs* and *Effectiveness of Neonatal Intensive* Care (Health Technology Case Study #l O), prepared for the Office of Technology Assessment, U.S. Congress, PB 82-101411 (Springfield, VA: National Technical Information Service, August 1981).

[4] Figures 2 and 3 reflect mortality and morbidity outcomes for very low birthweight infants who are born in Level 111 hospitals and have access to neonatal intensive care. Neonatal mortality rates for the general population of very low birthweight infants are significantly higher, and morbidity outcomes are unknown. Postneonatal mortality is not reflected in the figures, although such deaths probably have a substantial impact on overall outcome rates.

Figure 3.—Outcomes for Extremely Low Birthweight Infants (< 1000 grams) Born in Level III Hospitals, 1960-85



SOURCES For years 1980.85, Off Ice of Technology Assessment (see tables 7, 10, 11, and 12) For years 1960 and 1971-75, P Budetti, P McManus N Barrand, et al , The Costs *and Effectiveness of Neonatal Intensive Care* (Health Technology Case Study #10, prepared for the Off Ice of Technology Assessment, U S Congress, PB 82-101411 (Springfield, VA National Technical Information Service, August 1981)

NEONATAL CONDITIONS THAT CAUSE MAJOR MORTALITY AND MORBIDITY

Deaths among very low birthweight infants in intensive care are caused primarily by two conditions, respiratory distress syndrome and intraventricular hemorrhage. These conditions, along with retinopathy of prematurity, are also responsible for most of the long-term disabilities that plague NICU survivors. The sophisticated technology used in neonatal intensive care saves lives but also can exacerbate or even, in some cases, precipitate these problems. The application or withholding of such technologies presents an ongoing ethical dilemma for neonatologists.

Respiratory Distress Syndrome

Respiratory distress syndrome (RDS) is the most common problem in the neonatal nursery and the primary cause of mortality. It accounted for 18 percent of all neonatal deaths in 1978 (122). For babies weighing under 1000 grams, over 60 percent of the deaths have been attributed to RDS or to intraventricular hemorrhage, and for babies in the 1000- to 1500-gram category, 25 percent of the deaths are blamed on these causes (11).

Photo credit: Strong Memorial Hospital, Rochester, NY

Premature infants with severe respiratory distress syndrome usually require assisted ventilation.

Very premature infants experience respiratory distress because they lack an essential substance in the lung (or pulmonary surfactant) that reduces the surface tension along the alveoli and prevents the collapse of the pulmonary air spaces. The immense strain of having to force the alveoli open with each breath makes it increasingly difficult for these tiny babies to breathe independently. The pulmonary surfactant does not begin to coat the fetus's alveoli until between the 24th and 28th weeks of gestation, and it is not produced in major amounts until the 33rd week.

RDS occurs in 14 to 60 percent of premature deliveries at gestational ages between 28 and 35 weeks (174). Individual clinical centers report an even higher incidence of RDS among the extremely low birthweight babies. Kitchen and his associates reported an overall RDS incidence of 55 percent among the under 150&gram population **(82).** In the under 1000-gram group, Vohr and Hack found that 82 percent and Saigal and colleagues found that 74 percent of neonatal survivors had RDS (140,176).

Infants with RDS stay in the hospital on average twice as long as those without RDS (174). In 1984 at the University of California at San Francisco perinatal center, babies with RDS stayed in the NICU almost four times longer than babies without RDS and had hospital costs more than three times higher (126).

RDS may take mild, moderate, or severe form. Its clinical course is marked by increasing oxygen need and often by the need for assisted mechanical ventilation (breathing machines) to maintain adequate oxygenation and to remove carbon dioxide. The primary problem for RDS babies is the collapse of the alveoli which makes the work of breathing increase to physiologically intolerable levels. Two respiratory therapy techniques, developed over the past 15 years, prevent alveolar collapse by keeping up positive pressure on the lungs between breaths. Continuous positive airway pressure (CPAP) is used by itself to facilitate breathing, and positive end expiatory pressure (PEEP) is used in conjunction with positive-pressure ventilation. These innovations in respiratory therapies, as well as improvements in ventilator techniques such as the now widespread use of continuous flow pressure regulated ventilators, have contributed to diminished severity of RDS (167). Deaths associated with RDS have been decreasing since 1974, though it remains the leading cause of neonatal death (122).

Bronchopulmonary Dysplasia

Mechanical ventilation is essential for the survival of babies with severe RDS, but it disrupts the babies' normal cardiopulmonary physiology. Its prolonged use leads to a chronic lung disease called bronchopulmonary dysplasia (BPD). (Other conditions besides RDS can lead to ventilation of newborns and thus to BPD; these include pneumonia, meconium aspiration, patent ductus arteriosus, and apnea of prematurity (52).) BPD was first recognized and described in the 1960s (168). By definition, all infants who require mechanical ventilation during the first week of life, who remain dependent on supplemental oxygen for more than 28 days, and who have a characteristic chest radiograph have BPD (52).

BPD has become one of the most common sequelae of neonatal intensive care. A recent review article concluded that one-third of infants given mechanical ventilation and weighing less than 1500 grams at birth develop chronic lung disease (167). Two multicenter studies of 700- to 1500-gram babies in **1983 and 1984 also reported that overall about one-third of the survivors had chronic lung disease (8,10,69).** These studies found that female and black babies had significantly lower rates of chronic lung disease than their male and white counterparts in similar birthweight groups (10,69). Birthweight was the most significant predictor of lung damage. While only 19 percent of survivors with birthweights between 1000 and 1500 grams had chronic lung disease, 51 percent of survivors with birthweights between 700 to 1000 grams had BPD (69).

Reports from individual clinical centers conflict on the incidence of BPD among extremely small infants. Among the tiniest babies (under 800 grams), Buckwald and associates found that 75 percent of the survivors were still on a ventilator at 1 month, and Hack and Fanaroff reported that 70 percent of the survivors in their hospital developed BPD (24,61). On the other hand, Bennett and colleagues, also reporting on babies with birthweights under 800 grams, found only a quarter of the survivors developed BPD (13). Similarly, three reports on infants weighing less than 1000 grams found 62, 30, and 13 percent, respectively, of survivors developed BPD (140,48,71).

Significant mortality and long-term morbidity are associated with BPD during the postneonatal period **(86). Like RDS, bronchopulmonary dysplasia can take mild, moderate, or severe forms. About 1 out of 40 infants discharged from the hospital with BPD is so severely affected that respiratory support continues to be required at home (41,147). Rehospitalization and chronic respiratory problems are associated with BPD patients. Even after controlling for other risk factors like intraventricular hemorrhage, prolonged mechanical ventilation has been found to be associated** with poor developmental progress during the first 18 months of life in very low birthweight infants (21). When low birthweight infants with BPD were compared to a control group without the disease, the BPD infants had more respiratory diseases at 4 and 12 months and more severe neurodevelopmental sequelae at 2 years (177). Another study that followed BPD patients prospectively for 2 years post-term found that 85 percent of the children had lower respiratory tract infections and 50 percent of the infants required rehospitalization during their first year (98). Finally, a recent study of infants with BPD who were born between 1981 and 1983 confirmed the increased incidence of hospitalization and respiratory problems during the first year of life, but found that, for survivors, differences with the control group in neurodevelopment evident at 1 year had disappeared by 2 years of age (136).

Medical Practices

The detrimental effects of positive pressure ventilation have been known since 1965 (28). There is now some evidence that the way in which ventilatory support is medically managed may be associated with outcome. When Avery and her colleagues surveyed eight tertiary clinical care centers in **1983 and 1984 for their experience with BPD in infants weighing 700 to 1500 grams, they found that some institutions did significantly better than others (10).** Even after adjustments were made for weight distribution, sex, and race (but not for gestational age), differences among centers persisted. Among those centers studied, the intensive care unit at Columbia University had the best outcomes. At Columbia, the policies for respiratory management are dictated by a single physician, and the policies are followed at all times and for all babies. Instead of resorting to mechanical ventilation immediately, nasal CPAP is used to treat RDS early in the course of the disease and during the weaning from assisted ventilation. Attempts are made to minimize physical trauma; endotracheal tubes are used infrequently and for only short periods of time and muscle relaxants are never employed.

Medical practices and the use of technology vary widely among perinatal centers, and there are no clearly accepted norms for practice. Fur-

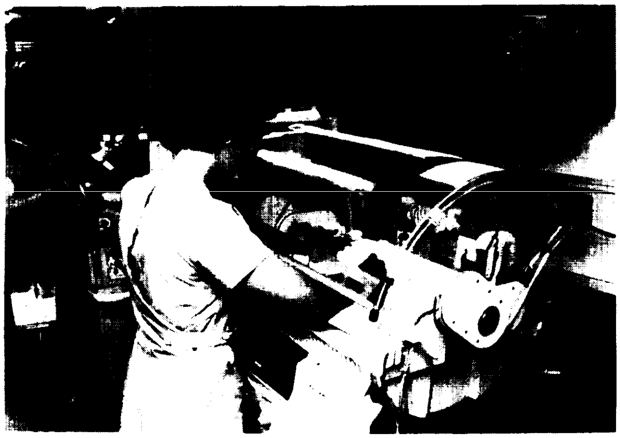


Photo credit: Strong Memorial Hospital, Rochester, NY

Coordinated management in the NICU and use of non intrusive therapies have been suggested as major factors leading to improved outcomes for very low birthweight infants.

ther systematic research is needed so that reliable comparisons among centers can be made and epidemiological methods used to evaluate ventilatory techniques (167).

Technological Advances

Improvements in existing ventilator techniques may hold promise for reducing the incidence of BPD in the future. In recent years, for example, there has been considerable research on several ventilator techniques, known collectively as high-frequency ventilation (HFV), that use rapid ventilator rates that may interfere less with normal cardiopulmonary physiology. Thus far, however, HFV has not been proven superior to conventional ventilation for treating neonates in respiratory failure **(20).**

Another new technology is extracorporeal membrane oxygenation (ECMO) which entirely bypasses the lungs using a process that closely duplicates the gas exchange function performed in utero by the placenta. ECMO can be used for as long as 2 weeks, allowing time for lung recovery by minimizing the harmful influences associated with high-pressure mechanical ventilation. ECMO has been used on more than 300 infants in 18 centers since 1975, but with very poor outcomes for premature, small infants. The incidence of intracranial hemorrhage is exceedingly high in these infants, and the bleeding may be aggravated by the heparin administered during ECMO. Unless further research can make ECMO available for infants who weigh less than 2000 grams, only small numbers of patients are likely to be treated by this technology. ECMO is currently indicated and may be lifesaving for term infants with meconium aspiration syndrome, persistent pulmonary hypertension, or diaphragmatic hernia (189).

The better solution for the problems posed by mechanical ventilation is to avoid the need for its use altogether. Two technologies are under development and testing that could substantially prevent RDS in the future. The first is the prenatal administration of glucocorticoids (steroids) to mothers in preterm labor in order to accelerate fetal lung maturation. The other technology, still experimental, is the introduction of exogenous pulmonary surfactant into the lungs of the newborn.

Steroid treatment of women in preterm labor has been used and studied for 16 years (7). Although all the studies support the efficacy of the steroids in reducing the incidence of RDS in the babies subsequently born, concerns remain about indications for use in specific situations, the influence of the steroids on infection during labor, and the effect of the steroids on the long-term development of the babies (43). Because of these concerns (particularly for patients with premature rupture of the membranes), some obstetricians use the steroids either selectively or not at all **(29).**

A multicenter, 7-year collaborative study on antenatal steroid therapy attempted to resolve these concerns. Reporting its results in 1985, the study confirmed the efficacy of steroids in reducing the incidence of RDS and in decreasing the severity of the disease in those affected. Furthermore, it found no evidence that the risk of infection is increased in the neonate or in the mother. And there is no effect of the steroid on either neurological maturation or function or developmental outcome during the first 3 years of life. However, the researchers also reported no effect on mortality and suggested that the effectiveness of steroid therapy is significant only for female offspring and only when the membranes are intact (174).

The collaborative study excluded infants under 28 weeks gestational age. A recent, retrospective study in Australia, designed to include a large number of very low birthweight infants at high risk of death, contradicted the findings of the collaborative study. It found survival is substantially improved by antenatal steroid therapy and that survival improves in both girls and boys (44).

Although the efficacy of steroid treatment is not resolved, the therapy clearly has several limitations. It does not work for all babies; at best, it lowers incidence and severity of RDS. And in addition, because steroid therapy must be initiated at least **24** hours before delivery in order to be effective, for obstetrical reasons many women in preterm labor cannot be candidates for its use.

Treating surfactant deficiency by administering exogenous natural or synthetic surfactant to the lungs of very premature babies at or soon after birth has the potential to greatly reduce the incidence of severe RDS. The basic biochemistry and physical chemistry of lung surfactant has been known for a long time, but research is ongoing for the best surfactant mixture, the optimum dose, and the timing and frequency of administration. At least seven recent randomized, controlled clinical trials testing natural surfactants (recovered from lung lavage of animals or humans) document that surfactant-treated infants have less severe RDS than control infants (51,74,84,102). The studies show a lower incidence of clinical RDS, lower ventilator requirements, and less oxygen supplementation in treated than in control infants. The treatment with human surfactant significantly decreased the risk of death and bronchopulmonary dysplasia (102). Several of the studies using bovine (cow) lung extract also showed decreases in the risk of death (158). While one recent multicenter trial in Great Britain using synthetic surfactant found reductions in mortality and the need for respiratory support **(104), other studies to date with synthetic surfactants have shown essentially no benefit for respiratory function (63,183).**

In none of the studies do all infants respond to the surfactant. Therefore, perfecting surfactant replacement will not be a panacea for RDS. Researchers hypothesize that some infants have respiratory distress from other causes, such as infection, or that, in extremely premature infants, dysfunction might by caused by other structural immaturities (9). Large-scale, multicenter trials are being undertaken in Europe and the United States to continue to test surfactant experimentally. It is probable that the necessary research and FDA approval process will take from 1 to 5 years before surfactant therapy will be generally available for preterm babies (8,149).

Intraventricular Hemorrhage

Along with RDS, intracranial hemorrhages, or brain bleeds, are responsible for the most deaths in the neonatal nursery (11). The most dangerous are intraventricular hemorrhages in which blood seeps into the cerebral ventricles, small cavities within the brain that secrete and convey cerebrospinal fluid, Almost all serious hemorrhages occur within the first or second day after birth (178). Once extensive brain damage has occurred there is little medicine can offer to improve the prognosis (178). An infrequent additional complication for babies with hemorrhage is the development of hydrocephalus, the dangerous distension of the head caused by the excessive buildup of cerebral spinal fluid. Fortunately many cases of posthemorrhagic hydrocephalus resolve spontaneously or respond to medical therapy (153).

Premature infants' blood vessels are particularly fragile, and a prevalent medical opinion is that the capillaries rupture and hemorrhage because of fluctuations in cerebral blood flow. Along with other causes including asphyxia, seizures, and pneumothorax, the use of intermittent positive pressure ventilation has been associated with hemorrhage **(42,178). It is believed by some that the infant's own respiratory effort, out of synchrony with the ventilator, causes changes in the cerebral blood pressure (123). Recent research has focused on ways, like muscle paralysis during ventilation, to prevent** such fluctuating patterns of cerebral blood flow velocity (123).

Previously recognized conclusively only on autopsy, the introduction of computed tomography scanning and later of ultrasound brain scanning revealed that 31 to 45 percent of infants weighing under 1500 grams at birth have subependymal or intraventricular hemorrhages (42,123). Most hemorrhages are graded mild and appear to cause no lasting clinical problems. Estimates vary on the proportion of cerebral hemorrhages that are severe as well as on the subsequent mortality and morbidity. Mortality is clearly higher in groups of infants with hemorrhage, as compared with other infants matched for birthweight or gestational **age (101), A partial review of institutional studies completed in the 1970s reported that mortality from severe hemorrhage ranged between 50 and 65 percent and that hydrocephalus developed in 45 to 100 percent of the survivors (153). More recent studies** have shown much lower fatality rates of 13 percent (42) and 6 percent (153) from intraventricular hemorrhage. In one of these studies only one infant (6 percent of the survivors) developed progressive hydrocephalus (153), while in the other study no infant required shunting for hydrocephalus (42).

The incidence and severity of hemorrhage are correlated with gestational age and birthweight. Infants born at less than 29 weeks gestation are especially at risk (42,153). Before 32 weeks gestation, a disproportionate amount of the total cerebral blood flow enters the periventricular circulation, and thus any disturbance of the blood flow tends to cause hemorrhage in this region of the brain (178). While the association of hemorrhage with gestational age is well established and founded on physiological evidence, birthweight alone is not as good a predictor of the likelihood of hemorrhage. Only one study reported results by birthweight category. At the Johns Hopkins Hospital in 1980, 90 percent of the babies weighing between **600** and 1000 grams had cerebral hemorrhages (36 percent of the babies had severe hemorrhages), but only 26 percent of the infants weighing between 1000 and 1600 grams had hemorrhages **(6** percent severe). This study found no evidence that the 600- to 800-gram babies had more severe hemorrhages than the other infants in the under 1000-gram" category, although the tiniest babies did have the highest overall incidence of hemorrhage (49).

Photo credit: March of Dimes Birth Defects Foundation

With appropriate therapy and support, the prognosis for even seriously handicapped very low birthweight infants improves over time.

Neurodevelopmental Outcome

Infants with severe intraventricular hemorrhages have a high rate of later neurodevelopmental handicaps. The risk of developing neurodevelopmental defects is correlated to the initial degree of hemorrhage (30,88,121). In a study of infants weighing under 1500 grams and born between 1976 and 1981, Papile and her colleagues at the University of New Mexico concluded that infants with mild grades of cerebral hemorrhage had no poorer outcomes than other babies of similar birthweight groups without hemorrhage. But they also found a major handicap in 58 percent of the infants with severe intraventricular hemorrhage, and multihandicaps in 45 percent of this group (121). An Australian study of extremely preterm babies born between 23 and 28 weeks gestation in 1981 reported that 8 of 12 infants with severe hemorrhage (67 percent) developed major disabilities (30). The study at Johns Hopkins Hospital of low weight babies born in 1980 found less disastrous results. At 12- to 22-month followup examinations, of 11 babies who had severe hemorrhages, 6 were normal, 3 had moderately retarded development, and only 2 babies or 18 percent had serious intellectual and motor impairment (153).

Retinopathy of Prematurity

Another affliction affecting premature infants is retinopathy of prematurity (ROP). The disease occurs in progressive stages beginning with retinal vasoconstriction, proliferation of blood vessels, scarring (cicatricial disease) of the retina, retinal detachment, and ultimately blindness (137). The disease is not invariably progressive and blindness is by no means an inevitable outcome. Many cases spontaneously regress to normal. Perhaps **25** percent of those with cicatricial disease go on to blindness (124).

The epidemic of ROP between 1942 and 1953 which resulted in about 10,000 blind children is perhaps the most widely known example of iatrogenic disease (156).[5] Because of technological advances, it was routine during that decade to administer high concentrations of oxygen to essentially every premature infant, and it was not until 1954 that a large, multicenter cooperative study indicted oxygen as the culprit in the exponential growth of ROP. The practice of routine oxygen administration was quickly abandoned, and the oxygen administered to infants with respiratory distress was given in much lower concentrations. But while there was a sharp decline in the prevalence of ROP during the 1950s and 1960s, researchers started reporting results by the early 1960s that created increasing uneasiness with the blanket policy of oxygen restriction for all premature infants. When oxygen usage was curtailed, studies showed that neonatal mortality and the incidence of spastic diplegia (a form of cerebral palsy) increased among premature infants. It was later estimated that for every case of blindness prevented, approximately 16 babies died due to inadequate oxygenation (37).

Today's medical opinion is that the cause of ROP is unknown but likely multifactorial, with oxygen being but one critical factor. Other risk factors suspected of playing a role in the etiology of ROP include too little oxygen in utero, infection, intraventricular hemorrhage, apnea, blood transfusions, hypercarbia, hypocarbia, patent ductus arteriosus, prostaglandin synthetase inhibiters, vitamin E deficiency, assisted ventilation, lactic acidosis, and prenatal complications (97). But overwhelmingly the primary risk factor is extreme prematurity, with almost all cases confined to this vulnerable group (137). The blood vessels in the immature retina are still developing, and it is believed that any disturbance in retinal circulation, whether too much oxygen or too little, can lead to the vessels' disordered and twisted growth. The very low birthweight, premature infant suffers from a number of the risk conditions that can disturb retinal circulation, and some cases of ROP appear to be unavoidable despite careful attention to oxygen therapy and monitoring.

Advances in neonatal care methods and the survival of more small and critically ill infants have contributed to a resurgence of ROP, which some call a second epidemic (137). Infants weighing under 1500 grams at birth are at greatest risk. Both the incidence and the severity of retinal disease increases with progressively lower birthweight and gestational age.

A 1981 review of the literature estimated that among infants weighing between 1000 to 1500 grams at birth, 2,2 percent have scarring ROP and 0.3 to 1.1 percent are eventually blinded. For infants under 1000 grams, approximately 22 to 42 percent have cicatricial ROP and 5 to 11 percent are blinded (124). By contrast, a Canadian population-based study conducted from 1977 to 1980 found that only 13 percent of infants under 1000 grams developed cicatricial disease, but overall 7 percent of the survivors were blinded (140). Two more recent studies of infants in NICUs weighing under **800** grams have reported that 25 percent (61) and 10 percent (80) developed cicatricial ROP. Finally, a controlled study investigating ROP from 1977 to 1980 in an Australian NICU found a lower incidence of serious scarring in the extremely low birthweight group than previously reported. Among the infants weighing under 1000 grams, only 3 percent developed scarring ROP; unfortunately all of them were blinded. This study also found in the 1000- to 1500-gram population that 2 percent developed cicatricial disease and 1 percent was blinded (187). These incidence figures agree with Phelps' estimates.

Although no technological fix is on the horizon, there has been renewed interest since the

[5] At the time of the epidemic, the disease was called retrolental fibroplasia. This term, still in use today, refers to the proliferation of scar tissue during the latter stages of the disease.

1970s in vitamin E as a preventive measure against ROP. Vitamin E was first used to prevent ROP in 1949. Although that initial study did find a significant effect, subsequent trials failed to confirm its efficacy, and when the role of oxygen was identified by the collaborative trial in 1954, both ROP and **its possible relation to vitamin E were dropped from the research agenda (125). Lucey and Dangman reviewed five recent clinical trials that used vitamin E prophylactically to treat either very low birthweight patients or patients with RDS.** The results of these studies, though difficult to compare, are conflicting. Some showed a reduction in both incidence and severity of ROP, others showed a lessened severity with no effect on incidence, and still others found no significant effect at all on the occurrence of ROP (97). While these results offer the promise of at least reducing the worst ROP, several researchers have urged caution and extensive further research. There are suspicions that vitamin E treatment may expose premature infants to increased risks of necrotizing enterocolitis and intraventricular hemorrhage (97,125). The potential negative side effects of vitamin E may outweigh the possible benefits.

Chapter 4

Financing Neonatal Intensive Care

Chapter 4

Financing Neonatal Intensive Care

INTRODUCTION

Neonatal intensive care is a very costly service for hospitals to provide. In the 12 children's hospitals studied by the National Association of Children's Hospitals and Related Institutions (NACHRI), neonates represented only 8 percent of the admissions, but 21 percent of the patient days and 25 percent of the hospitals' costs (110). Neonatal care was the most costly category of service provided by the children's hospitals and, except for organ transplantation, involved the most extreme lengths of stay.

Because neonatal intensive care is so expensive, it is important to examine the mix of third-party payers responsible for reimbursing providers and the extent to which payments cover the costs of providing care. Few studies directly examine the insurance status of neonatal intensive care unit (NICU) patients. Of 580 admissions to two NICUs in San Francisco in 1984, 30 percent were covered by Medicaid, 47 percent by commercial insurance, and the remaining 23 percent by other payers, self-pay, or were not covered under any plan (126). Of course there is considerable variation among hospitals. For example, while Medicaid admissions constituted 24 percent of the total cases in NACHRI's study, the proportion of Medicaid admissions to total admissions ranged from 11 to 42 percent in individual children's hospitals (110).

In general, hospitals consider the Medicaid program to be a poor payer. Data from the American Hospital Association survey show that while Medicaid paid only 19.8 percent of total net revenues in children's hospitals, Medicaid beneficiaries accounted for 23.3 percent of all inpatient days (107). Especially in the past, hospitals have financed the provision of such uncompensated care—charity care and bad debts—by "cost-shifting" and charging private sector payers—commercial insurers, some Blue Cross plans, and patients who pay their own bills—proportionately more than their share of the costs of the care.

Hospitals typically charge a daily rate for general care in the NICU and add separate charges for ancillary and special services that accrue during the hospital stay. But these charges may be unrelated to actual costs. When particular services have unfavorable payer mixes or are so expensive that their costs cannot be fully reimbursed, hospitals may underprice or not fully allocate overhead costs to the services. In general, both intensive care services and pediatric services in general hospitals fall into this category. In practice hospitals often subsidize these losses by pricing other services, which are used by a greater proportion of charge-paying patients, much higher than their actual costs. The emergence of competitive forces in today's health care market, however, is curtailing the ability of hospitals to subsidize uncompensated care through cost-shifting among payers.

One reason is that the proportion of patients paying on the basis of charges is decreasing. To keep their occupancy levels high, more and more hospitals are participating in preferred provider organizations (PPOs). In return for negotiated lower prices, the PPO beneficiaries (usually former charge-paying patients) agree to use the designated "preferred providers. " A conservative estimate of the number of people enrolled in PPOs in the summer of 1986 was about 16.5 million (40). Health maintenance organizations (HMOs), which typically have risk-sharing or prospective payment arrangements with their hospitals, have also increased their share of the marketplace. HMO subscribers increased from 3.5 million in 1972 to 27.7 million by 1987 (73,169). Insurance companies that previously paid on the basis of charges for most patients are also using other methods to limit hospital payments. Like the public payment programs, Medicare and Medicaid, private insurers are moving toward prospective methods of reimbursement. Prospective payment can take many forms (cavitation, per diem, or per case payment), but, as payment rates are tightened to eliminate profit, all will ultimately limit the opportunity of providers to cost-shift.

REIMBURSEMENT PRACTICES

Since the enactment of the Medicare prospective payment system in 1983, seven Blue Cross/ Blue Shield (BC/BS) plans have implemented payment systems based on diagnosis-related groups (DRGs), and another three plans are involved in pilot programs using DRGs (134). As of June 1985, 13 States had also adopted some form of prospective per case payment system in their Medicaid programs (see also the following section on Medicaid policies) (91). Although the mechanisms used by these systems to calculate the payment amounts for the DRGs usually differ from the Medicare system as well as among BC/BS plans and Medicaid programs, there is considerable concern in the provider community about how fairly DRG payments would reimburse hospitals for neonatal intensive care (110,130).

NACHRI simulated 1984 Medicare DRG payments in 12 children's hospitals and found the hospitals suffered their greatest financial losses from the neonatal cases (110). Without heavy reliance on special payments for outliers (cases with statistically unusual lengths of stay), Medicare's payments for neonatal cases would have fallen far below the hospitals' operating costs. The neonatal cases involved the highest incidence of outliers of any major DRG grouping in the children's hospitals. Similarly, another study analyzing NICU admissions in six teaching hospitals in California found that when the Medicare program's definition of outliers was used, half of all admissions were classified as outliers (130). A study of 1981 newborn discharges in Maryland also found 50 percent of charges in the three prematurity DRGs were generated by outliers (16).

NACHRI has proposed replacing Medicare's 6 neonatal DRGs with 30 new DRGs based on 6 birthweight categories and further subdivided by the presence of major diagnoses, surgery, and the prolonged use of mechanical ventilation. Their proposed set of DRGs would explain 28 percent of the variation in length of stay among neonatal cases while the current Medicare DRGs explain only 16 percent of the variation (111). Overall, NACHRI concluded that, for children's hospitals, the measurement of neonatal care is the most critical issue in constructing a prospective payment system, and that the volume of neonatal cases is a major factor in determining the balance of costs and revenues under the various reimbursement schemes (110).

Even if payments for neonatal care equal costs under prospective payment methods, hospitals will continue to have revenue shortfalls because of their eventual inability to cost-shift under these payment methods. Hospitals have recourse to other sources of revenue for uncompensated neonatal care. Block grant funds available to States under the Maternal and Child Health Services Program are sometimes used to directly fund neonatal intensive care for children whose family incomes are not low enough to qualify them for Medicaid (135). Moreover, all States have general assistance programs that reimburse health providers for care rendered to certain Medicaid-ineligible population groups (12). The extent to which these State and county payment programs actually cover hospital losses depends heavily on geographic location, as States vary widely in coverage and level of payment. Finally, some State programs, instead of targeting indigent individuals, directly support hospitals providing substantial amounts of indigent care. These States generate revenues for uncompensated care through taxes or through surcharges on all hospitals' revenues (12).

MEDICAID

The Medicaid program is the major source of public funding for low-income women and babies. About **6** percent of all newborns whose deliveries are subsidized by Medicaid require neonatal intensive care, but this care is so expensive that it represents about 30 percent of all Medicaid expenditures for maternity care (77). Medicaid pays for about 10 percent of all births in the United States, but with wide variations across States. Within Federal guidelines, each State designs and administers its own program. As a result there are substantial State-to-State differences in eligibility requirements, benefits, limits on services, and reimbursement policies,

Policies

Medicaid coverage for newborns is dependent on the eligibility of their mothers. Although the income criteria for Medicaid eligibility are so strict that many poor people are excluded from coverage, family structure and employment status are no longer barriers to eligibility for pregnant women and their babies. Legislation passed in 1984 and 1986 relaxed eligibility restrictions on first-time mothers and married pregnant women with some income from employment. The Deficit Reduction Act of 1984 (Public Law 98-369) also required States automatically to cover the health costs of newborns in eligible families. Previously, each newborn infant had to be individually certified as eligible for Medicaid, sometimes leading to administrative delays in coverage with costly ramifications for providers (39), Furthermore, the Consolidated Omnibus Budget Reconciliation Act of 1986 (Public Law 99-272) mandates Medicaid coverage for women and newborns for **60 days** postpartum, regardless of changes in the eligibility status of the mother. Thus, any newborn whose mother met the income requirements for Medicaid prior to delivery is assured of at least **60** days of automatic Medicaid coverage.

Inpatient hospital services, including neonatal intensive care, are mandated covered services under the Federal guidelines for Medicaid. However, some States place limits on the number of days per admission or per year that a beneficiary is covered for inpatient care. As of June 1985, 13 States had such day limits, although several programs allowed extensions for medical necessity (91). Coverage of inpatient days is also limited according to diagnosis in some Medicaid programs. Likewise, States can limit the number of covered physician visits. Thirteen States limit physicians' inpatient visits, but in general the limits are one or two visits per day for allowable hospital days (171).

Prior to the Omnibus Budget Reconciliation Act of 1981, which freed States from following traditional Medicare payment practices, States generally used reasonable cost-based reimbursement principles. By June 1985 only 14 Medicaid programs still used the retrospective per diem method (91). Because of both economic and political pressures, most States adopted alternative hospital reimbursement strategies in their Medicaid programs. **As** discussed earlier, 13 States use some form of prospective per case rate, either on a simple per admission basis or a discharge diagnosis basis. Except for Utah, all these programs use State-specific data, rather than Medicare data, to calculate DRG weights (134). The data sources used include hospital cost report data, paid claims files, and Medicaid claims data. Another 21 States use a prospective per diem as the unit of payment (91). Although diagnosis is not taken into account, some of these systems do provide different per diem rates for general inpatient care and for intensive care. Finally, five States use an annualized payment system whereby the hospitals receive a negotiated or contractual global fee from Medicaid. Twenty-four of the State Medicaid programs have developed special adjustments that recognize costs associated with the provision of uncompensated care.

Expenditures for Neonatal Intensive Care

Table 13 shows that of babies whose deliveries are reimbursed by Medicaid, the proportion requiring neonatal intensive care varies widely by State. In the 13 States responding to a survey by the Alan Guttmacher Institute, the proportion of

Table 13.—Medicaid Recipients in Neonatal Intensive Care Units (NICUs), and Medicaid Expenditures, Selected States, 1983-85[a]

State and year	Number of Medicaid infants in NICUs[b]	Percent of total Medicaid births treated in NICUs	Total Medicaid expenditures for NICUs ($ x 1,000)[b]	Medicaid expenditure per infant in NICU
California (FY84)	6,152	6.2	$92,069	$14,966
Florida (FY85).	3,965	20.3	12,256	3,091
Idaho (CY85)	—	—	880	—
Louisiana (CY83)	395	4.3	7,322	18,538
Maryland (FY85)	477	4.3	9,703	20,341
Massachusetts (FY83).	1,052	8.8	—	—
Michigan (FY85)	790	2.6	19,717	24,958
Missouri (FY85)	440	4.6	1,623	3,689
Nevada (CY84)	55	3.7	1,618	29,414
North Carolina (FY84)	—	—	3,012	—
Ohio (FY85).	—	—	48,410	—
Oregon (FY85)	285	6.2	578	2,028
Pennsylvania (FY85)	1,449	6.6	8,681	5,991
South Carolina (FY85)	418	5.7	3,718	8,894
Tennessee (FY85)	—	—	2,101	—
Vermont (FY85)	—	—	439	—
Washington (FY85)	359	2.9	1,776	4,947
Wisconsin (CY83)	428	3.2	2,164	5,056

[a]Methodology for estimates: Louisiana—estimated neonatal intensive care data furnished by State; Massachusetts—reported neonatal intensive care data based on partial reporting by the State, reported dataon infants in neonatal intensive care as a percentage of Medicaid births are only for facilities reporting both kindsof data; Ohio—reported neonatal intensive care expenditures, annualized from 13 months of data; South Carolhra and Washington—estimated neonatal intensive care data furnished by the State; Vermont—reported neonatal intensive care expenditures, annualized from 14 months of data,

[b]Excludes prepaid plans

SOURCE A M Kenny, A. Torres, N Dittes, et al,, "Medicaid Expenditures for Maternity and Newborn Care in America, " *Family Planning Perspectives* 18(3):103-110, May/June 1986

Medicaid babies admitted to NICUs averaged 6.1 percent but ranged from only 2.6 percent in Michigan to an overwhelming 20.3 percent in Florida. The *6.1* percent average for all surveyed States is consistent with national data on the proportion of all newborns who receive intensive care. (See ch. 2.) Because the Medicaid population is generally considered to be at higher risk, a greater incidence might have been expected (77).

Table 13 also shows enormous differences in the per-patient Medicaid payments for neonatal intensive care. Of the 12 Medicaid programs responding to the 1985 survey, average NICU expenditures range from $2,000 in Oregon to **$29,400** in Nevada. The average expenditure in the 12 States is $11,800 (77). The average Medicaid expenditure is lower than the average hospital costs reported for NICU infants in children's hospitals and teaching hospitals, but higher than the average costs for all sick neonates in Maryland Level III hospitals. (See ch. 2.) The NACHRI study found that Medicaid patients in children's hospitals are more costly to treat than the general pediatric population and represent a more difficult case mix (110).

It is difficult to draw conclusions from the dramatic variation in expenditures among States in part because the scope of each State program is so different and in part because of the nature of neonatal intensive care. The NACHRI study of children's hospitals showed that neonatal care is the most costly service provided by the pediatric hospitals and involves the longest lengths of stay. Therefore, in States that extend Medicaid benefits to the medically needy (people who do not meet income requirements until they "spend-down'" on medical expenses) babies not normally qualified for Medicaid may become eligible because they are in neonatal intensive care units. In addition, the clinical composition of the Medicaid NICU populations in the States responding to the survey is unknown. Because extreme outliers are common in neonatal intensive care, a few cases with extraordinary costs could severely skew a State's average expenditures in a single-year reporting period.

'Through the "spend-down" provision, families or individuals, who meet all the categorical requirements for Medicaid except income, can become eligible for Medicaid under the medically needy program if they have high medical expenses that reduce income below the medically needy maximum.

Chapter 5

Access to Neonatal Intensive Care

Chapter 5

Access to Neonatal Intensive Care

INTRODUCTION

The concept behind regional perinatal care is a coordinated, cooperative system of physicians and hospitals in which maternity patients and their newborns at high risk are identified early and the optimal techniques of obstetrics and pediatrics are appropriately applied (34). Numerous studies document the higher survival rates for very low birthweight infants born in Level 111 hospitals versus those born elsewhere within the same geographic area. Table 14 summarizes these reports and lists, for comparative purposes, neonatal mortality rates for several geographic regions and for the United States as a whole. In those population-based studies that identify place of birth by hospital type, the survival rates for very low birthweight infants born in perinatal centers are significantly better than for those born in either Level I or Level II hospitals. ’ In New York City, for example, Paneth and his colleagues concluded that in 1978 preterm and low birthweight infants born

[1]The single exception was a 1978 study in Iowa which found higher survival rates in small Level I hospitals than in Level 111 hospitals for very low birthweight infants. Since this was after the regionalized system was in place, a likely explanation is that physicians working in the smallest hospitals referred the highest risk obstetric cases to the perinatal center (66). Moreover, a followup study showed the survival advantage in small Level I hospitals disappeared after 1978. Babies born in the Level 111 center were most likely to survive (67).

Table 14.— Regional Neonatal Mortality Rates[a] for Very Low Birthweight Infants, 1976.81

Reference[b]	Year of birth	Population	Birthweight (grams) < 1000[c]	1001-1500[c]		< 1500
Saigal (139)[d]	1976-78	Hamilton-Wentworth County, Ontario	617	122		343
Paneth (119)	1976-78	New York City	—		529’	
		Level III	—		487[e]	
Vogt (175)	1977	Southern California	628[f]	241		371[f]
Hein (66)	1978	Iowa	—	—		470
		Level III	—	—		440
Goldenberg (54)	1976-80	Alabama	663	212		—
		Level III	497	118		—
Cordero (35)	1977-79	Franklin County, Ohio			580[e]	
		Level III			470’	
Gortmaker (59)	1978-79	3 States Louisiana,	521[g]	185		—
		Tennessee, Washington	484[g]	139		—
		Level III				
Shapiro (151)	1978-79	8 geographic areas	—	—		439
Saigal (140)[d]	1977-80	McMasters Health Region	541	—		—
		Level III	462	—		—
Kitchen (81)[d]	1979-80	Victoria, Australia	744	—		—
		Level III	710	—		—
Newns (1 14)	1979-81	West Midlands, England	713	276		417
		Level III	522	175		267
Buehler (26)	1980-81	Georgia	642	161		—
U.S. Department of Health and Human Services (172)[h]	1980	U.S.A.	648	187		431

[a]Deaths per 1.000 live births
[b]See references in the back of this case study for full citations
[c]Some studies reported birthweight categories as 500-999 and 1000-14999
[d]Deaths reported to hospital discharge
[e]Includes 501- to 1250-g Infants
[f]Birthweight Categories 701 to 1000 and 701 to 1500 g
[g]Includes 750. to 1000-q infants
[h]Rates for singleton births

SOURCE Off Ice of Technology Assessment, 1987

Photo credit: Yale University and March of Dimes Birth Defects Foundation

Identifying high-risk pregnancies and appropriately referring mothers to perinatal centers is key to regionalization.

outside Level III centers had a 24 percent higher risk of dying (120). During the same time period, Gortmaker and associates studied birth and death certificates in four States and found that black infants with birthweights between 1000 and 1500 grams were more than twice as likely to die during the neonatal period if they were born in a rural hospital instead of in a perinatal center (59).[2]

One component of regionalization is the efficient transfer of sick newborns from their hospital of birth to facilities capable of providing sophisticated critical care. But even a well-functioning infant transfer system cannot erase the mortality differences across hospital levels. In the New York City study, deaths were assigned to hospital of birth to assess the effect of interhospital transport on neonatal mortality. Despite the transfer of **48** percent of the low birthweight infants from the Level I hospitals to Level 111 units, the neonatal death rates were significantly higher in Level I hospitals (119). Thirty percent of all neonatal deaths in the study population occurred in the first 4 hours of life. These early deaths cannot be influenced by infant transport and point to difficulties in the resuscitation and immediate neonatal management of low birthweight infants in the more poorly equipped and staffed hospitals.

The advantages and disadvantages of neonatal versus antenatal (maternal) transfer continue to be argued in the medical literature. Some studies find no significant differences in mortality **(17,103)** and others report advantages for those infants referred prior to delivery **(64,89),** but all the institutional studies report only on the infants who reach the intensive care unit. The newborns selected for transfer introduce bias into these studies. On the one hand, the sickest and most premature neonates may die at referring hospitals before transport can be arranged, and transfers could therefore be more viable than their cohort. On the other hand, preterm infants without morbidity are probably cared for at their hospital of birth rather than being transferred. Moreover, transported infants may suffer inadequate temperature maintenance or delays in the initiation of mechanical ventilation before their admittance to the neonatal intensive care unit (NICU), leading to a relatively sicker group of transferred babies (81).

Several population-based studies support maternal over neonatal transport. In Hamilton-Wentworth County in Ontario, researchers estimate that the pre-delivery transfer of selected pregnant women to the regional center accounted for 28 percent of the improvement in survival among the very low birthweight babies born after the introduction of neonatal intensive care (157). In the British Mersey Region in **1980,** neonatal survival was significantly better for those very low birthweight infants who were transferred prior to birth than for infants who were not transferred or were transferred after delivery (93). Moreover, the difference between the survival rate for those infants transferred before delivery and those infants born to mothers who had booked at the perinatal center was not significant. And in the State of Victoria, Australia in 1979 and 1980, both survival and outcome were better for tertiary center births than for those born elsewhere (81). The Australian study, which examined only infants with birthweights under 1000 grams, found a significantly higher prevalence of severe functional handicaps in the outborn children than in either the inborn or the antenatal transfer

[2]This was the most disadvantageous differential in survival reported in the study, and it should be noted that overall survival among black infants was greater than among white infants at the same level of hospital care (59).

groups. Several other institutional studies also report an increased incidence of intraventricular hemorrhage or respiratory distress syndrome in infants transported neonatally as compared with inborn infants, implying these infants were not adequately stabilized at birth **(31,89,103).** Although the birth of a premature infant cannot always be anticipated, there is ample evidence that, ideally, pregnant women at high risk should be transferred to a perinatal center prior to delivery.

LEVEL II HOSPITALS

Besides questioning the efficacy of relying on neonatal transport from Level I hospitals, the population-based study in New York City also raises doubts about the effectiveness of neonatal intensive care in Level 11 facilities. The study showed that while there was a survival advantage for low birthweight babies in a Level II hospital over a Level I hospital during the first 4 hours of life, that advantage disappeared by 28 days. Improvements in neonatal mortality rates from 1976 to 1978 were statistically significant only for infants born in Level III units. The researchers concluded that intrapartum management and postnatal stabilization were performed well in Level II hospitals, but that the management of later complications of low birthweight such as respiratory failure was less expertly handled (119).

Paneth and his colleagues blamed the virtual absence of infant transfers from Level II units to Level 111 facilities for the discouraging mortality rates **(120).** Support for these views comes from the State Division of Health Services in North Carolina. Their study of perinatal mortality rates from 1969 to 1979 for very low birthweight infants in North Carolina found that by 1979 the Level II centers had higher mortality rates than either of the other two hospital levels (117). This study also concluded that Level II hospitals seldom referred infants or maternity patients. The author urged greater participation in a coordinated referral system.

One reason Level II hospitals might not refer high-risk mothers and infants to nearby Level III hospitals is competition. A major way that hospitals compete for patients is through the scope and quality of services. Childbirth is often a family’s first contact with hospitalization. Transfer of mother or child to a nearby Level III hospital could jeopardize the family’s continuing relationship with the Level II institution. Particularly in urban settings, where competition among hospitals is keenest, Level II facilities may be reluctant to refer to Level III units (128).

Since the New York City and North Carolina studies, there has been a nationwide movement to upgrade the capabilities of Level II units (144). Conversely, some Level II hospitals have terminated their specialized neonatal intensive care services. In New York City, for example, the number of facilities offering Level II nursery services declined from the study period high of 20 to only 14 in 1982 (65,120). Moreover, the extent to which there is a problem may well be related to the region of the country. For example, a Level II nursery in Georgia, which published its experience for 1976 to 1978, referred 62 percent of its newborns with birthweights under 1500 grams to a Level III facility (76). The Level II facility unit considered that its capabilities included the care of moderately ill newborns weighing 1500 grams or more and convalescing neonates who had been returned from the Level III facility.

The guidelines published by the Committee on Perinatal Health in 1977 and reiterated jointly by the major professional associations in 1983 specifically list gestation of less than 34 weeks or birthweight of less than 2000 grams as indications for transfer from Level II units to Level III units (4,34). But the American Academy of Pediatrics acknowledged the wide range of functional capabilities existing within the definition of a Level 11 unit in a 1980 statement by its Committee on Fetus and Newborn (3). Some units provide care only slightly more complex than Level I nurseries, while others have capabilities approaching Level III centers. The referring practices of these centers may vary just as widely. And while the Committee on Fetus and Newborn clearly states that it is undesirable for Level II units to provide neonatal cardiology and surgery services, no mention is made of referring practices for low birthweight infants beyond the requirement for ongoing liaison and consultation with a Level III center. Each Level II unit is urged to assess its own capabilities for delivering care in terms of personnel and facilities.

CONCENTRATION OF BIRTHS IN LEVEL III HOSPITALS

Although regionalization is often given credit for many of the improvements in perinatal outcome over the last decade, little is known about the extent to which high risk mothers and infants are actually redistributed to the appropriate levels of care. Several groups have reported comparisons of areas that did or did not have a regionalized program. In 1975, the Robert Wood Johnson Foundation funded eight sites to promote coordinated systems of perinatal care for entire geographically defined regions, comprising about 6 percent of the births in the United States. An evaluation compared mortality rates both before and after regionalization and in program and comparison regions. Neonatal mortality rates declined in both types of regions, but no greater reduction was noted for the program-funded regional network. The investigators concluded that regionalization had become widespread and extended into the comparison areas without the encouragement of specific funding (100). Likewise, Siegel and colleagues looked at two comparable areas in North Carolina (one funded to develop a perinatal system) and reached much the same conclusions as the Robert Wood Johnson Foundation researchers (155). However, a third program launched in 1979 specifically to improve perinatal health care (including high-risk maternal referrals to Level III centers) in 10 rural areas with histories of high infant mortality did show sharp declines in neonatal mortality rates while rates in control areas did not change (58).

Photo credit: Kay Chernush, photographer, Children's Hospital National Medical Center, Washington, DC

Time is crucial in the transport of very sick newborns.

The Robert Wood Johnson Foundation evaluation also studied the extent to which high-risk births occurred in tertiary care centers. By 1979, almost 60 percent of all very low weight births in the demonstration areas were delivered in perinatal centers, compared with only 36 percent at the beginning of the decade. Similar changes occurred in the comparison areas, although the percentage of very low weight births in the Level III units was lower than in the demonstration areas (100). Those results, along with the results of other studies examining the concentration of very low weight births in Level III units, are shown in table 15. All the studies demonstrated a shift in the site of delivery over time, with high-risk deliveries increasingly moved to the perinatal centers. Such changes indicate that with regionalization some antenatal assessment of risk is occurring and that the management of high-risk pregnancies is being transferred to the Level III units before delivery.

But table 15 shows there is wide variation among areas in the extent to which infants of very low birthweight are born in Level III hospitals. The largest area, the Robert Wood Johnson Foundation regions representing *6* percent of all births nationally, shows the highest concentration of very low weight births in tertiary centers. Iowa, a rural State, shows one of the lowest concentrations. However because of low population density and distance considerations, a single Level III center serves the entire State, and Iowa is considered to be successfully regionalized **(66).**

The degree to which access to Level III services varies within regions among different subgroups in the population is difficult to determine. Gortmaker and colleagues examined racial and urban/rural differences in four States. (See table 15.) The lowest concentration of very low weight births in Level 111 centers occurred among whites in Louisiana and Ohio; **23** percent of white very low birthweight infants were born in regional centers in these States. Black infants, in general, had better access to specialized services. In Tennessee more than 50 percent of the black very low birthweight infants were born in perinatal centers. Residents of rural areas were always less likely than their urban counterparts to be born in Level III units, but again, black rural infants were more likely than white rural infants to be born in specialized centers (59).

These data on the concentration of very low weight births in Level III centers do not fully describe the extent to which sick newborns actually receive services in Level 111 units. The contribution of infant transport systems to increased access cannot be assessed. However, the wide variation among geographic areas in the concentration of high-risk births points to inequities in the availability of neonatal intensive care.

Table 15.—Concentration of Births of Infants Weighing Less Than 1500 Grams in Level Ill Hospitals

Reference [a]	Year of birth	Population	Births in Level Ill hospitals: < 1500 grams (percent)	Births in Level Ill hospitals: All births (percent)
Hein (66)	1978	Iowa	23	7
Nugent (1 17)	1979	North Carolina	47	
McCormick (100)	1978-79	8 Robert Wood Johnson Foundation geographic areas	59	43
		Comparison Areas	47	31
Gortmaker (59)	1978-79	LA: white, urban	27	
		black, urban	59	
		white, rural	14	
		black, rural	31	
		Ohio: white, urban	26	
		black, urban	35	
		white, rural	13	
		black, rural	11	
		TN: white, urban	40	
		black, urban	67	
		white, rural	38	
		black, rural	45	
		WA: white, urban	42	
		white, rural	44	
Goldenberg (53)	1980	Alabama	56	32
Lobb (93)	1980	Mersey, Great Britain	28	
Information Service Center (72)	1984	Maryland	54	31

[a] See references in the back of this case study for full citations

SOURCE Off Ice of Technology Assessment. 1987

BARRIERS TO MATERNAL AND NEONATAL TRANSPORT

Level III hospitals may refuse admission for a neonatal transfer for a number of reasons. The lack of available beds is the reason proffered in most instances. Although the average occupancy nationwide in Level III units is only 73 percent, occupancy in some intensive care nurseries does consistently approach 100 percent. (See ch. 2.) It is also likely that a few hospitals use the excuse of full occupancy to turn away infants whose care would not be adequately reimbursed. As discussed in chapter 2, neonatal intensive care is one of the most costly services provided by hospitals and entails some of the longest lengths of stay. Uninsured infants may be deemed undesirable admissions by some hospitals. Moreover, because Medicaid is often considered a poor payer which does not fully reimburse a hospital's costs, even Medicaid coverage may not ensure entry. (See ch. 4.)

There is no legal requirement that forces hospitals to admit every child, regardless of ability to pay. Depending on when a neonatal intensive care service was started, the need for such services may have been analyzed by health planners under State certificate-of-need legislation. However, once a certificate-of-need is granted, the State has no ongoing authority over how services are operated. The Joint Commission on Accreditation of Hospitals, which reviews the operations of hospitals and lists staffing, equipment and procedural guidelines for neonatal intensive care units, does not address issues of access to treatment (75). Some hospitals are legally required to provide a certain amount of charity care to indigent individuals if they received Federal funds for hospital construction and renovation under the Hill-Burton Act of **1946.** Currently, about 4,200 hospitals in the United States are still fulfilling their Hill-Burton obligations **(182).**

Likewise, hospitals are not required to preadmit high-risk pregnant women for their deliveries, even if the hospital serves as the designated perinatal center for the region. In fact, most hospitals have policies requiring advance payment in full for deliveries if the maternity patients do not have insurance. However, in March 1986 the Consolidated Omnibus Budget Reconciliation Act was passed, and it prohibits any Medicare-participating hospital from refusing to treat or from transferring any woman already in labor (50).

The same financial incentives operate for physicians. Obstetricians and pediatricians may be leery of accepting non-paying or partial-pay patients. Survey data show that obstetricians lag behind other specialties in the extent to which they accept Medicaid patients. The average Medicaid reimbursement rate for obstetrical care is at least one-third lower than the average private fee, and the gap between the two amounts is widening over time **(170).**

On the other hand, obstetricians with paying maternity patients may not want to refer high-risk cases to the perinatal center and risk losing their fees. Many of the Level III hospitals are university-affiliated with closed medical staffs; non-faculty physicians are not allowed admitting privileges.

The escalation in recent years of malpractice actions, especially against obstetricians, has probably had a side effect of improving access to perinatal services for high-risk women. Concerns about possible malpractice litigation would encourage community obstetricians to refer high-risk maternity cases to regional centers. Obstetricians might particularly employ such "defensive medicine" tactics for low-income high-risk women because the physicians have poor financial incentives to keep their patients.

Finally, the perceptions of physicians about neonatal mortality and outcome affect access to neonatal intensive care. Several studies show that physicians substantially underestimate the potential survival of low birthweight infants (56,185). The obstetrician's understanding of prognosis in turn influences his or her management of premature labors, such as the decisions to utilize electronic fetal monitoring, to perform cesarean sections for fetal distress, or to transfer mother and baby prior to delivery to a Level III facility **(56).** These early management decisions may determine whether the newborn infant actually survives.

A survey of obstetrical residency programs in 1981 found that at less than 28 weeks gestational age there is still considerable variation among hospitals in how labor and delivery are managed. Based on the survey, about one-half of university training programs consistently performed cesarean sections for fetal distress at 27 weeks gestational age and one-third of the nonuniversity residency programs routinely performed cesarean deliveries under these conditions. (The average birthweight for a 27-week infant is between 950 and 1000 grams.) This study points to a lack of consensus among obstetricians on how aggressively labor and delivery should be managed between 25 and 28 weeks gestational age (55).

THE TINIEST BABIES

Once a low birthweight infant is in a Level III hospital, through birth or transfer, access to neonatal intensive care is almost assured. In practice, the almost universally followed approach in the NICU today is to initiate aggressive treatment for all infants at birth (160,165). Broad latitude has traditionally been given to doctors and parents involved in making the difficult decisions about treatment for premature or sick neonates. But in part in reaction to the so-called "Baby Doe" rules, pediatricians, anxious about their legal liability, are increasingly treating virtually all newborns, including extremely premature infants with very low birthweights. Although the rules came about in response to several "Baby Doe" cases involving selective nontreatment for infants with Down's syndrome, spina bifida cystica, and other congenital anomalies, the primary controversy in the medical community revolves around the tiniest infants who are born at the threshold of viability.[5]

The Department of Health and Human Services (DHHS) issued a "Notice to Health Care Providers" in May 1982 informing hospital administrators that, under Section 504 of the Rehabilitation Act of 1973, they risked losing Federal funds if treatment or nourishment was withheld from handicapped infants. The so-called "Baby Doe" rules were promulgated in interim regulations by DHHS the following March and in final regulations in January 1984. Facilities were required to post notices in nurseries and provide access to medical records for Federal investigators. Although the Supreme Court ruled in 1986 that the 1973 Rehabilitation Act could not be used to justify the regulations because there was no evidence that hospitals denied care to babies solely because of handicap, Congress had in the meantime passed legislation dealing with medical neglect in the 1984 amendments to the Child Abuse Prevention and Treatment Act (Public Law 98-457) (181). These amendments define medical neglect in the treatment of disabled infants as child abuse and give the oversight responsibility for implementing the law to the States' child-abuse agencies (164). Both the American Academy of Pediatrics, which vehemently opposed the initial Baby Doe regulations, and Right to Life groups, which supported them, participated in reaching compromise language. Regulations implementing this legislation went into effect in June 1985.

The new regulations permit "reasonable medical judgment" to be used in making decisions about the care of disabled newborns and explicitly lists three exceptions when withholding medical treatment (other than appropriate nutrition, hydration, or medication) is not "medical neglect" (106,164). The exceptions deal with situations where treatment would merely prolong dying or would be "virtually futile" in terms of the survival of the infant and, under these circumstances, the treatment itself would be inhumane.

The regulations also encourage hospitals to set up Infant Care Review Committees. A 1985 survey by the American Academy of Pediatrics of hospitals with NICUs found that nearly 66 percent had an ethics body, up from 56 percent the previous year. However, the survey also found that slightly more than half of the committees had considered no cases during the previous year (1). Apparently, Baby Doe cases are relatively rare with most conflicts resolved by parents and health professionals (181),

[5] Most experts believe that there is an anatomical threshold of fetal development (especially for lung and kidney development) at about 23 to 24 weeks before which time fetal survival is not possible even with modern techniques (148).

Although the Baby Doe rules have raised public debate on the issue, their legal impact on treatment decisions for extremely premature infants is unclear (90). Aside from the limited clout of the new regulations (withholding Federal dollars from the State child protection service agency), the language is ambiguous and open to interpretation. In the case of extremely low birthweight infants, "reasonable medical judgment" is divided on whether it is "virtually futile" to offer treatment. The guidelines accompanying the regulations admit that "virtually futile" does not mean absolute certainty and that the prospect of death need not be imminent (106). If most physicians understand the law this way, a minimal effect on treatment decisions might be expected. On the other hand, in today's malpractice-wary climate, physicians may react by treating aggressively all but the most clearly hopeless cases so as to avoid any possibility of liability for medical neglect (105).

In practice, physicians often employ guidelines for treatment based on their own observations of prognosis. Under such informal policies, infants who are born weighing less than 500 grams are not resuscitated in most hospitals. In some institutions, this boundary on treatment might extend to babies under 600 grams or even under 750 grams, Of course gestational age and the condition of the infant are also taken into consideration. Without the application of sophisticated life-extending technologies, like respirators, these infants are almost certain to die. Although, as discussed, the Baby Doe regulations do not force evaluation of such policies, many neonatologists cite the Federal rule as a primary reason for the aggressive treatment of smaller and smaller neonates. At least one published report blames the intrusion of the Baby Doe regulations into the NICU for the unnecessary and costly treatment of conjoined twins when there was no hope for survival **(150).**

Practicing defensive medicine is a negative incentive for most physicians, and it should be noted that the same neonatologists who mention legal considerations also point to the now many publicized successes with extremely tiny babies. The normal outcome for some of these infants encourages imitation. More importantly, it is impossible during the first weeks of life, even with today's most sophisticated technology like ultrasound brain scans, to predict accurately an infant's eventual outcome (21,163).

Chapter 6

Economic Analysis of Neonatal Intensive Care

Chapter 6

Economic Analysis of Neonatal Intensive Care

INTRODUCTION

This case study has shown that neonatal intensive care is a high-cost technology that demonstrably saves the lives of low birthweight babies. But the long-term consequences of providing intensive care are more difficult to evaluate. Over the lifetimes of the infants treated in neonatal intensive care units (NICUs), are medical care costs increased or reduced? Likewise, what are the effects on the pain and suffering of patients and their families? Is it possible that some severe handicaps in children are considered by families to be worse than death?

Cost-effectiveness analysis (CEA) can provide insight to these issues by comparing the costs, benefits, and quality of life implications of neonatal intensive care in a single economic evaluation. Ideally, CEA compares the costs and the health effects of alternative strategies, such as the provision of neonatal intensive care with another kind of intervention for low birthweight babies. The expected changes in health effects are arrayed against the net medical care costs incurred by providing each alternative approach to neonatal care.

Unlike CEA, cost-benefit analysis attempts to place dollar values on all consequences, both positive (benefits) and negative (costs), arising from alternative courses of action. The alternative with **the** highest level of monetary net benefit (or lowest net cost) is preferred to others. If the net benefit is greater than zero, the alternative is "cost saving" and considered worthwhile on efficiency grounds alone. Because it is so difficult to place a value on the benefits of a strategy, cost-benefit analysis often proves inadequate. Some researchers have calculated the lifetime economic productivity of survivors, but this is certainly an incomplete surrogate for the benefits of a life-saving intervention. How can a value be placed on the pain, suffering, anxiety, emotional distress, or grief in patients and their families, especially when these consequences occur at different times in the future? These psychosocial benefits (or losses) defy measurement (179).

Cost-effectiveness analysis escapes the problem of trying to value benefits by using the effectiveness measure (e.g., quality-adjusted life years) as a proxy. Net costs per unit of health effectiveness are calculated and compared with other programs with similar health goals. The interpretation of results from cost-effectiveness analyses remains problematic, however, because methodological differences in study design make it difficult to directly compare one CEA evaluation to another.

COST= EFFECTIVENESS AND COST-BENEFIT STUDIES

The earlier OTA study on neonatal intensive care by Budetti and his colleagues concluded that neonatal intensive care for infants weighing 1500 grams or less was marginally cost saving when the value of the lifetime economic productivity of survivors was estimated. Treatment of the subgroup weighing under 1000 grams cost more in net medical costs than was saved in productivity if outcomes from 1971 to 1975 were used. When mortality and morbidity rates from later in the 1970s were used in the calculation, however, treatment of the extremely low birthweight infants also became cost saving. The benefits accruing from the lifetime earnings of the increased number of normal survivors outweighed the costs incurred by the increase in the absolute number of severely handicapped **(25).**

Budetti and his colleagues compared the costs of neonatal intensive care with less intensive care of ill newborns. Using mortality and morbidity rates gleaned from the literature, they relied on a cost-benefit economic model that assigned dollar values based on the assumptions that normal survivors are economically productive; nonsurvivors are relatively inexpensive; and seriously defective survivors are both expensive and not productive. These hypothetical scenarios may not have adequately mirrored the true life experience of NICU survivors. In addition, their analysis did not take into account the psychosocial costs and benefits of neonatal intensive care that were discussed previously.

The most comprehensive economic evaluation conducted to date was undertaken by a group of Canadian researchers (19). They studied the mortality and morbidity of all very low weight infants born to the residents of a southern Ontario county before (1964 to 1969) and after (1973 to 1977) the introduction of neonatal intensive care. The assessment of survivors' health included a classification of health states that measured physical, social, role, and emotional function as well as health problems. To take into account these psychosocial costs, a sample of parents was then surveyed on the desirability or undesirability of the health states relative to one another. For example, parents rated some chronic dysfunctional states as worse than death. The survey results were then used to weight life-years for quality. These quality-adjusted life-years (QALYs) were the measure used to adjust additional years of life (decreasing mortality) for the long-term disabilities that some survivors have as they live out their life expectancies.

Health outcomes were calculated for two birthweight groups: infants weighing 1000 **to** 1499 grams and infants weighing 500 to 999 grams. Like many other studies, the Canadian group found that the rate of survival to hospital discharge increased with neonatal intensive care. And, while the introduction of neonatal intensive care also resulted **in increases in quality-adjusted life-years for the very low birthweight infants as a whole, for the subgroup of infants weighing less than** 1000 grams, the increase in quality-adjusted life-years was lower than the increase in unadjusted additional life-years, implying a poor quality of life for many of these tiniest surviving infants. In fact, although the proportion of serious handicaps among survivors did not increase significantly, the increased absolute number of survivors resulted in a greater number of handicapped children (70).

Costs were estimated for all neonatal care and for lifetime followup health care and other special services, **such as institutional care or special education. The results of the economic evaluation performed by the Canadian group are shown in table** 16. For the group weighing 1000 to 1499 grams at birth, the incremental cost of neonatal intensive care was $82,969 per survivor at hospital discharge. Similarly, for the 500- to 999-gram birthweight group, the neonatal intensive care program cost $142,929 per survivor.

By every economic measure, neonatal intensive care for infants weighing 1000 to 1499 grams was more cost-effective than neonatal intensive care for infants weighing under 1000 grams. Projected over a lifetime,[1] the neonatal intensive care pro-

[1] Neonatal intensive care requires the early expenditure of large sums of money to achieve later gains. Therefore, a discount rate of 5 percent was applied to costs, earnings, and effects (QALYs) occurring in the future in order to convert future values to their equivalent present value.

Table 16.– Measures of Economic Evaluation of Neonatal Intensive Care for Very Low Birthweight Infants (5 Percent Discount Rate), 1984[a]

	Birthweight (grams)	
Period	1000-1499	500-999
To hospital discharge:[b]		
Cost/additional survivor. . . .	$82,969	$142,929
To age 15 (projected):		
Cost/life-year gained	8,506	17,012
Cost/QALY gained[c].	10,737	55,917
To death (projected):		
Cost/life-year gained	4,044	12,968
Cost/QALY gained[c].	4,462	31,235
Net economic benefit (loss)/live birth	(3,626)	(22,450)
Net economic cost/QALY gained[c].	1,394	24,403

[a] Values were converted to 19& U.S. dollars from 1978 Canadian dollars.
[b] All costs and effects occurred in Year one.
[c] QALY denotes quality-adjusted life-years.

SOURCE: M.H. Boyle, G.W. Torrance, J.C. Sinclair, et al., "Economic Evaluation of Neonatal Intensive Care of Very -Low-Birth-Weight Infants, " *N. Eng. J. Med.* 308(22):1330-1337, June 2, 1983.

gram cost $4,462 per quality-adjusted life-year gained for the 1000- to 1499-gram birthweight group and $31,235 per quality-adjusted life-year gained for the under 1000-gram group. Borrowing from cost-benefit analysis, the researchers also calculated net economic benefit (or loss) by taking into account the anticipated future earnings of survivors. In this analysis, there was a net economic loss in employing neonatal intensive care over nonintensive care for both weight groups. However, for infants weighing 1000 to 1499 grams the increased costs of treatment were very nearly offset by increased lifetime earnings. When the discount rate was set lower than 3½ percent, the net economic benefit per live birth was positive. Not so for the birthweight group weighing under 1000 grams. Gains in survival and quality-adjusted life-years were obtained at a considerable increase in neonatal costs and subsequent health care costs. These costs could not be repaid through lifetime earnings.

CONCLUSIONS AND POLICY IMPLICATIONS

The results of the Canadian study raise a number of issues. One is whether the same conclusions would be reached if the study were conducted today. For the time period studied, the mortality, morbidity, and cost figures used by the Canadian group did not differ markedly from other population-based and institutional reports for the same birthweight groups. However, since 1977 there have been both substantial gains in survival and increases in costs. During the period studied by the Canadians, the risk of mortality declined more rapidly for the 1000- to 1500-gram birthweight group than for smaller babies. Since then, the most rapid reduction in mortality risk has been for the 750- to 1000-gram birthweight group. (See ch. 3.) Better rates of survival would tend to improve the cost-effectiveness of neonatal intensive care, and this impact would be greater for the under 1000-gram birthweight group.

OTA calculated the incremental cost of neonatal intensive care in producing a survivor by using the recent data on mortality and hospital costs that are developed in this case study (table 17). Baseline survival rates, prior to the introduction of neonatal intensive care, were taken for the years 1961 to 1965 and compared with the most recent, available survivor rates, those for 1981 to 1985. OTA's results are remarkably similar to those found in the Canadian study. (Both tables 16 and 17 are in 1984 U.S. dollars.) Compared with the Canadian costs, OTA found the cost per additional survivor to be about $3,000 more expensive for infants with birthweights between 1000 and *1500* grams and about *$24,500 less* expensive for infants with birthweights under 1000 grams. The impact of improved survival rates for extremely low birthweight infants was very strong, because the average hospital costs in the Canadian study for the under 1000-gram birthweight group were less than one-half the average costs used in the OTA calculation. If only mortality is taken into account, the cost-effectiveness of neonatal intensive care relative to no special care for the smallest babies (those under 1000 grams) has improved since 1977.

Limitations of data prevented OTA from examining the implications of long-term morbidity on costs in a separate cost-effectiveness analysis. The proportion of NICU survivors with serious handicaps has remained stable since the Canadian study, but the rate of severe disability increases with decreasing birthweight. (See ch. 3.) The recent declines in mortality mean that, especially among the under 1000-gram birthweight group,

Table 17.—Cost of Neonatal Intensive Care Per Additional Survivor, 1984

	Birthweight (grams)	
	1000-1499	500-999
Average hospital cost[a]	$36,153	$ 49,617
Additional survivors per 1,000 live births from 1960 to 1980[b]	419	419
Cost per additional survivor	$86,284	$118,418

[a] From table 4, mean of the average hospital costs per infant reported by the three groups of hospitals.
[b] From table g, change in inborn neonatal mortality rates per 1,000 live births from 1961-65 to 1981-85.

SOURCE: Office of Technology Assessment, 1987 there are now both more normal survivors and more handicap victims, (See figures 2 and 3 in ch. 3.) It is unclear how the new mix of survivors would affect the economic equation.

Costs have increased since 1978, and these increases have outpaced inflation by more than 75 percent in the United States. Infants treated in neonatal intensive care use resources more intensively than previously, and resource use is inversely correlated with birthweight. (See ch. 2.) These increases in medical care costs, though they contribute to improved health outcomes, would tend to decrease the cost-effectiveness of neonatal intensive care. Moreover, the lifetime costs for custodial care for a severely disabled person have risen too. A recent estimate of the cost for caring for a severely handicapped child (in 1982 dollars) is $22,590 per year (170).

In all likelihood the conclusions of the Canadian study would still pertain today. Neonatal intensive care results in both increased survival and increased costs, Moreover, neonatal intensive care becomes more expensive as it is employed in increasingly marginal cases.

One way to increase the cost-effectiveness of neonatal intensive care is to try to identify which newborns are most likely to survive, and, in particular, experience higher quality lives (14). For example, because birthweight is such a powerful predictor of both survival and morbidity, analysis of birthweight groups by 100 gram increments can lead to refinements in the conclusions of the Canadian group. Researchers in Rhode Island analyzed lifetime costs for infants weighing 500 to 1000 grams and born between 1977 and 1981 (180). Taking into consideration long-term therapeutic and custodial care for handicapped children as well as initial hospitalizations, they estimated costs in 1982 dollars ranging from $362,992 per survivor for infants with birthweights between 600 and 699 grams to $40,647 per survivor for those weighing 900 to 999 grams. Their cost-benefit analysis showed that when estimates of lifetime earnings were added to the equation, only infants with birthweights from 900 to 999 grams had future earnings that exceeded total costs.

Such analyses help to refine the economic equations, but the question should not be whether to *deny care to any particular infant on the basis of high costs.* It is expected that a successful intervention like neonatal intensive care will add to overall medical costs. Moreover, there are many ethical, social, and legal reasons why intensive care should not be withheld from a newborn, no matter what its size and gestational age. (See ch. 5.) Most importantly, neonatologists are unanimous in stating that it is impossible to predict outcome at birth. Many healthy babies would be lost if blanket policies of withholding care were promulgated. Doctors, in conjunction with parents, have traditionally grappled with decisions about individual patients and they must continue to do so. Data on cost-effectiveness can be one component of what are, ultimately, value judgments.

Policymakers can more directly use the results of cost-effectiveness analyses to guide priorities in expenditures for health care. For example, it is not clear that society is spending more per quality-adjusted life-year for neonatal intensive care than for other programs such as dialysis, kidney transplantation, coronary artery bypass surgery, or bone-marrow transplantion (14,186). In such a comparative context, neonatal intensive care can be judged to be more or less worth its costs. Better cost-effectiveness information about diverse programs can help both policymakers and physicians make consistent and well-founded choices.

Appendixes

Appendix A

Glossary of Acronyms and Terms

List of Acronyms

AHA —American Hospital Association
BPD —bronchopulmonary dysplasia
BC/BS —Blue Cross/Blue Shield
CEA —cost-effectiveness analysis
CPAP —continuous positive airway pressure
DRGs —diagnosis-related groups
ECMO —extracorporeal membrane oxygenation
HFV —high-frequency ventilation
HMO —health maintenance organization
IVH —intraventricular hemorrhage
MDC —major diagnostic category
NACHRI—National Association of Children's Hospitals and Related Institutions
NICU —neonatal intensive care unit
NIH –National Institutes of Health
OTA –Office of Technology Assessment (U.S. Congress)
PEEP —positive end expiatory pressure
Pro —preferred provider organization
QALY —quality-adjusted life-year
RDS —respiratory distress syndrome
ROP —retinopathy of prematurity
SIDS —sudden infant death syndrome

Glossary of Terms

Antenatal transfer: The transport of pregnant women to the appropriate level of care prior to delivery.

Assisted ventilation: Mechanical assistance in performing or controlling the breathing function.

Baby Doe rules: Federal regulations issued from 1982 to 1984 under Section 504 of the Rehabilitation Act of 1973 that prohibited hospitals from withholding nourishment or care from handicapped infants. The Supreme Court ruled in 1986 that the 1973 act could not be used to justify the regulations. Meanwhile Congress passed the 1984 amendments to the Child Abuse Prevention and Treatment Act that permitted "reasonable medical judgement" to be used in making decisions about treatment for disabled newborns.

Birthweight: Weight of an infant at the time of delivery. Birthweight can be recorded in either pounds/ounces or grams.

Birthweight-specific mortality rate: Deaths in a birthweight category per 1000 live births in the same birthweight category.

Bronchopulmonary dysplasia: A chronic lung disease in newborns, often defined by a characteristic appearance of the lungs on X-ray and the use of assisted ventilation for more than 4 weeks.

Case mix: A measure of the mix of cases being treated by a particular health care provider that is intended to reflect the patients' different needs for resources.

Cerebral palsy: A paralysis of varying severity that results from nonprogressive damage to the brain at or around birth.

Congenital anomalies: Birth defects that result from imperfect development during pregnancy.

Continuous positive airway pressure (CPAP): A respiratory therapy technique that prevents alveolar collapse by keeping up positive pressure on the lungs between breaths.

Cost-benefit analysis: An analytical technique that compares the costs of a technological application to the resultant benefits, with both costs and benefits expressed by the same measure. This measure is nearly always monetary.

Cost-effectiveness analysis (CEA): An analytical technique that compares the costs of a technology or of alternative technologies to the resultant benefits, with cost and benefits/effectiveness not expressed by the same measure.

Cost saving: An economic concept referring to the results of cost-benefit analysis when the net benefit is greater than zero.

Diagnosis-related groups (DRGs): A patient classification scheme based on the principal diagnosis, secondary diagnoses, surgical procedures, age, and discharge status of the patients treated in hospitals.

Extremely low birthweight: Birthweight of less than 1000 grams (2 lb 2 oz).

Gestational age: The number of completed weeks elapsed between the first day of the last normal menstrual period and the date of delivery.

Handicap rate: See serious *handicap* and *moderate handicap.*

Health maintenance organization (HMO): A health care organization that, in return for prospective per capita payments, acts as both insurer and provider of comprehensive but specified medical services.

Hydrocephalus: The distension of the head caused by the excessive buildup of cerebral spinal fluid.

Infant mortality: Death in the first year of life. It includes neonatal mortality and postneonatal mortality.

Intracranial hemorrhage: Bleeding in the brain.

Intraventricular hemorrhage: Bleeding into the cerebral ventricles, small cavities within the brain that secrete and convey cerebrospinal fluid.

Level I hospitals or facilities: Hospitals that provide only normal newborn care under the regional system for perinatal services.

Level II hospitals or facilities: Hospitals in the regional system for perinatal services that provide specialized neonatal care but lack some components and expertise found in Level III facilities.

Level **III hospitals or facilities: Hospitals** in the regional system for perinatal services that provide the most sophisticated neonatal intensive care.

Low birthweight: Birthweight of less than 2500 grams (5 lb 5 oz).

Major diagnostic category (MDC): The **23** principal divisions in the **DRG patient classification** scheme. The diagnoses in each MDC correspond to a single organ system or etiology and in general are associated with a particular medical specialty.

Mechanical ventilation: See *assisted ventilation.*

Medicaid: A federally aided, State-administered program of medical assistance for low-income people meeting categorical requirements.

Moderate handicap: Disabilities that include moderate mental retardation (IQ or developmental quotient between 70 and 80).

Morbidity: The condition of being diseased or disabled.

Neonatal intensive care: The constant and continuous care of the critically ill newborn.

Neonatal intensive care unit (NICU): A specialized hospital unit combining high technology and highly trained staff that treats seriously ill newborns,

Neonatal mortality: Death in the first 28 days of life.

Neonatal mortality rate: Deaths during the first 28 days of life per 1000 live births.

Neonate: A newborn infant less than a month old.

Neonatologist: A pediatrician specializing in newborn care.

Neurodevelopmental outcome: A measure of neurological and developmental status.

Outliers: Hospital cases with statistically unusual lengths of stay under the DRG patient classification scheme.

Perinatal care: Medical care pertaining to or occurring in the period shortly before and after birth, variously defined as beginning with the completion of the 20th to 28th week of gestation and ending 7 to 28 days after birth.

Postneonatal mortality: Death between the first 28 days and the end of the first year of life.

Postneonatal mortality rate: Postneonatal deaths (28 days to under 1 year) per 1,000 neonatal survivors.

Preferred provider organization (PPO): A form of health care delivery system in which an agreement is made between providers and purchasers that patients who seek medical care from the "preferred providers" will obtain benefits such as reduced cost sharing. In return for the potential increase in volume of patients, the preferred providers may agree to discount their charges, to accept capitated payments, or to submit to enhanced utilization review.

Preterm infant: A newborn whose gestational age is less than 37 completed weeks.

Prospective payment: Payment for medical care on the basis of rates set in advance of the time period in which they apply. The unit of payment may vary from individual medical services to broader categories, such as hospital case, episode of illness, or person (cavitation).

Pulmonary surfactant: A substance in the lung that reduces the surface tension along the alveoli and prevents the collapse of the pulmonary air spaces.

Quality-adjusted life-year (QALY): An economic measure used in cost-effectiveness analysis to express benefits / effectiveness.

Regionalization: The organization and coordination of perinatal services, including a three-tiered system of hospital care, by geographic region.

Respiratory distress syndrome (RDS): An acute respiratory disorder which, in premature infants, is thought to be caused by a deficiency of pulmonary surfactant. When RDS is in severe form, patients often **need mechanical assistance to breathe.**

Retinopathy of prematurity (ROP): A retinal disease afflicting premature infants that can lead to retinal scarring, retinal detachment, and blindness,

Serious handicap: Disabilities that include severe mental retardation (IQ or developmental quotient below **70),** cerebral palsy of significant degree, major seizure disorders, or blindness.

Steroid treatment: A drug regimen administered to pregnant women in preterm labor in order to accelerate fetal lung maturation.

Surfactant: See *pulmonary surfactant.*

Very low birthweight: Birthweight of less than 1500 grams (3 lb 3 oz).

Appendix B

Acknowledgments

The development of this case study was greatly aided by the advice and thoughtful review of a number of people. Several individuals contributed unpublished data which permitted the calculation of recent estimates on the costs and effectiveness of neonatal intensive care. The author and other OTA staff would like to thank the following people:

Mary Ellen Avery
The Children's Hospital
Boston, MA

Michael Boyle
McMaster University
Hamilton, Ontario

Philip Davidson
University of Rochester Medical Center
Rochester, NY

John M. Driscoll, Jr.
Columbia-Presbyterian Medical Center
New York, NY

Marvin Feuerberg
Office of Technology Assessment
Washington, DC

Susan Goldbecker
The Children's Hospital at Albany Medical Center
Albany, NY

Patty Goldberg
Information Service Center
Baltimore, MD

Maureen Hack
Rainbow Babies and Children's Hospital
Cleveland, OH

Elicia Herz
Office of Technology Assessment
Washington, DC

Jeffrey Horbar
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Burlington, VT

L. Stanley James
Columbia-Presbyterian Medical Center
New York, NY

John Kiely
Sergievsky Center
Columbia University
New York, NY

Howard Kilbride
Children's Mercy Hospital
Kansas City, MO

Sharon Kovzelove
Children's Hospital National Medical Center
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Ernest Kraybill
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Chapel Hill, NC

Burton Kushner
University of Wisconsin Medical School
Madison, WI

John Muldoon
National Association of Children's Hospitals and
Related Institutions
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Karen E, Pape
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Ciaran S. Phibbs
Institute of Health Policy Studies
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Elaine Power
Office of Technology Assessment
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Richard Schreiner
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Rachel Schwartz
National Perinatal Information Center
Providence, RI

Donald Shapiro
University of Rochester Medical School
Rochester, NY

Ann Stewart
University College London
London, Great Britain

George Torrance
McMaster University
Hamilton, Ontario

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