would have a greater adverse impact on blacks than on whites unless all correctable factors that predispose to low birthweight had previously been dealt with. This result would be predicted, because the disproportionate number of black births in the high-risk very low birthweight groups accounts for virtually all of the black-white differences in neonatal mortality rates. Thus, it appears that medical care of the newborn may be partially compensating for the socioeconomic, nutritional, and other inequities that play a large role in determining interracial differences in prematurity rates. For this reason, it is critical to be able to predict the result of programs aimed at reducing those inequities before considering reductions in the availability of neonatal intensive care.

DEFINITION OF NEONATAL INTENSIVE CARE

Neonatal intensive care is defined by the American Academy of Pediatrics as the constant and continuous care of the critically ill newborn (4). This type of care involves many individual medical technologies, highly specialized physicians and nurses, and proximity or linkage to obstetric services.

Neonatal intensive care is typically delivered in organized hospital units. The facilities delivering neonatal care are classified into three groups or levels, depending on the sophistication and scope of the services the facilities are equipped and staffed to provide. The distinctions between the three levels blur considerably in the field, however, and the definitional confusions that result substantially complicate collecting and analyzing data on costs and utilization.

History of Neonatal Intensive Care

In the early part of this century, most sick newborns died within the first few hours of life. Premature newborns were not expected to live more than a few days. In 1878, Dr. E. S. Tarnier instituted the use of a "warming chamber''—the first incubator—and was able to increase the chance of survival for a large number of premature newborns (117). Similar machinery was widely used in international expositions and later became common at amusement park sideshows featuring "incubator babies. " Eventually, incubators gained acceptance in the medical community and became standard equipment in most hospitals with maternity services. As the survival period for premature infants lengthened, problems of nutrition and disease to which such infants are prone became evident, and research on these problems began.

Facilities and medical techniques for care of the newborn have progressed most rapidly since 1965 with the evolution of perinatal[1] medicine and the development of associated medical technology. Care provided the newborn has passed through many phases and now involves the use of highly technological diagnostic and therapeutic techniques and sophisticated life-support systems.

Most newborn medical care problems arise in severely premature[2] infants and for that reason, a large part of neonatal intensive care consists of using machines and other therapies to compensate for the lack of full development of the infant. The most common technologies are respirators and positive pressure breathing devices for treatment of respiratory distress syndrome

[1]Perinatal: The period around the time of birth, now generally defined as from 20 weeks of gestation up to 28 days of life.

Neonatal: The period from the moment of live birth up to but not including the moment at which the infant completes the 28th day of life.

[2]Premature infants comprise two groups: 1) infants who were born too soon (before the 38th week of gestation), but whose weight and development are Appropriate for their Gestational Age ("preterm AGA"); *2)* infants who were born early and who are underdeveloped, or Small for their Gestational Age ("preterm SGA"), due to intrauterine growth retardation. In addition, some infants born at term (after 37 weeks gestation) are Small for their Gestational Age ("term SGA") and have birthweights in the same range as truly premature infants but are relatively more mature. Most of the literature relevant to this paper focuses on birthweight alone, and does not mention gestational age. Consequently, we will most often use the terms "low birthweight " (2,500 g *or less) or* "very low birthweight" (1, *500* g or less); when we use the term "premature, " it is generally in reference to very low birthweight infants who may be SGA or AGA, but are most often preterm. For ease of reference, 2,500 g is approximately 5 lb 8 oz, while 1,500 g is about 3 lb 4 oz.

(RDS), also called hyaline membrane disease (HMD).[3] Once it was discovered and accepted that oxygen therapy can cause blindness in premature infants, many new technologies were developed to monitor more carefully the levels of inspired and circulating oxygen. The oxygen content of a premature infant's arterial blood is often measured several hundred times during the serious stages of illness. Newer techniques that monitor oxygen saturation continuously are now being used.

Other therapeutic and diagnostic innovations are also highly technological. Intravenous hyperalimentation,[4] advanced thermoregulatory apparatuses, cardiac catheterization, and "microchemistry" laboratory tests using only minute samples of infant blood are all associated with expensive, sophisticated machinery. Computerized ventilator systems may further refine mechanical ventilation in the future (101). Technology and research made it possible to treat severe jaundice with "exchange" blood transfusions, representing a major breakthrough in neonatal care. More recently, the need for this complicated and dangerous procedure has been reduced by two other innovations: phototherapy (exposure of the jaundiced infant to artificial light), and passive immunization of mothers at risk for Rh disease. Progress in the diagnosis of intracranial hemorrhage has led at least one pediatric radiologist to recommend computer-assisted tomographic scans in the first week of life for all babies weighing less than 1,500 g at birth (34).

Along with changes in neonatal intensive care have come changes in the training of the physicians and nurses who deliver such care. Before 1960, responsibility for the care of the newborn was shared among general pediatricians, obstetricians and general practitioners. In the early to mid-1960's, pediatricians with special interest in caring for sick newborns began to specialize in early infant care, leading to the development of neonatology as a pediatric subspecialty (111). By 1979, 835 neonatologists had been certified by the American Board of Pediatrics since the first exam was held in 1975 (6). Although 200 neonatology training programs exist in the country today, none is subject to formal accreditation (6).

Levels of Neonatal Intensive Care

Hospitals delivering neonatal intensive care are generally separated into three levels based on the intensity of care each is equipped and staffed to provide. Level I hospitals provide minimal or normal newborn care, Level II hospitals are those considered to provide intermediate care, and Level III hospitals are those considered to provide the most intensive care of the three levels.

Definitions of the three levels of neonatal care are found in the recommendations of the 1976 report of the Committee on Perinatal Health (32) and in the 1977 report of the American Academy of Pediatrics (4).[5] These recommendations were developed as guidelines for the regional development of perinatal health services. The definitions of each level are briefly summarized below.

Level I hospitals are those "whose function is to provide services primarily for uncomplicated maternity and newborn patients, and those with minor complications" (32). Level I hospitals must also be able to provide for detection and identification of existing and potential problems. Their emergency services may include some forms of temporary intensive care techniques to manage unexpected complications before the patient can be transferred to a higher level facility. Level I hospitals also include nurseries able to provide supportive or recovery care for infants transferred back from Level II or III units after the infants' acute problems have been resolved.

[3]RDS is a clinical diagnosis of pulmonary immaturity; HMD was originally a pathological diagnosis made at postmortem examination. The terms are now often confused and used interchangeably. In this text, they should be taken to refer to the clinical entity requiring neonatal medical care, unless otherwise specified.

[4]The intravenous administra ion of nutrients.

[5]The American Academy of Pediatrics was a participant on the Committee on Perinatal Health, but had published a separate set of recommendations and standards prior to the Committee report, Although the recommendations are virtually identical, the presentations differ,

Level II hospitals are those that can "provide a full range of maternal and neonatal services for uncomplicated patients, for the majority of complicated obstetrical problems, and certain types of neonatal illnesses" (32). Infants treated in a Level II intermediate care unit may include those with mild RDS, unstabilized respiratory function (periodic apnea), hyperbilirubinemia (jaundice), hypoglycemia, and superficial and localized infections. In addition to all the services of a Level I hospital, Level 11 hospitals provide more 24-hour services, more sophisticated equipment, and more medical personnel trained in specialized care of the newborn.

Level III hospitals have intensive care units which "must be able to provide the full range of resources and expertise required for the management of any complication of pregnancy or of the newborn" (32). Level III units in hospitals with obstetric services have facilities for extremely ill infants born in the hospital or transported from surrounding regions and facilities for moderately ill and normal infants. In addition to serving as referral centers, these hospitals provide consultation services, conduct continuing education programs, and coordinate and direct transport of referred patients. Transport can also be classified as a special care service by itself. Transport of a sick newborn requires specialized, portable equipment to provide care, and trained medical and nursing staff to manage the move.

The major difference between the services of a Level II unit and those of a Level III unit is the Level III unit's capacity for continuous and constant long-term intensive care and immediate availability of subspecialty consultants in fields such as cardiology and surgery. Level III services include continuous cardiopulmonary support and capability to treat those infants requiring long-term intravenous therapy, hyperalimentation, major surgery, and treatment of sepsis (widespread infection).

Definitional Problems

The terminology for defining levels of care, unfortunately, is not precise. A Level III hospital, for example, is generally expected to provide care at all levels of intensity. Such a hospital might have as many as four nursery units: normal newborn, continuing care, intermediate care, and maximal care. In that case, only the maximal care site might be called the "neonatal intensive care unit" (NICU). More commonly, however, levels would be combined into one or two units, so that the NICU would include all but the normal newborn area. Moreover, Level III hospitals generally have Level II and Level I beds, as well as Level 111 beds. Level II hospitals often refer to their newborn special care center as a "neonatal intensive care unit, " and may claim to have some Level III beds.

Neonatal services in many hospitals do not reflect the three defined levels of care. The rapid advancement of medical technology, escalating costs of medical equipment, training requirements for medical personnel, and a rush to apply new knowledge with minimal planning to guide development has led to a diversity of services provided at various hospitals offering neonatal care in a region. As a consequence, the services provided in different facilities classified at the same level can vary considerably, making a standard level of care difficult to define in practice.

The diversity of services, personnel, and equipment has several causes. In some areas, one or two pediatric subspecialists might be available at a Level II hospital enabling certain infants to be cared for at that facility. Similar infants would require transport from a Level II unit without the same subspecialists to a Level III unit. Also, a hospital may maintain specialized equipment (e. g., a newborn mechanical respirator) which is not required for the facility's designated level, but which allows that hospital to provide a service normally performed at a higher level facility, In addition, a hospital may attempt to treat most serious neonatal problems even though the facility may not include one or more of the ancillary services or subspecialty consultants recommended for Level III hospitals by the Committee on Perinatal Health (32).

Regulatory programs and reimbursement policies further complicate the definitional problems by creating incentives for hospitals to classify their units inappropriately. For example, ratesetting programs may be more likely to approve higher rates for a Level III unit than for a Level 11 unit. Certificate-of-need programs, however, may apply very restrictive criteria to Level III facilities while not even recognizing Level II nurseries as special units (23).

Additional confusion results from the lack of agreement among hospitals, professional medical groups, State planning, regulatory and funding agencies, and the Department of Health and Human Services (DHHS)[6] on a uniform definition of each level of care. This confusion is evident throughout the country. A 1979 report prepared for the Health Resources Administration of the Department of Health, Education, and Welfare (HEW) (113) showed that only 12 of 33 States with certificate-of-need programs responding to a survey had published standards for obstetrical and neonatal care; 9 States provided no definitions for Level I neonatal care; 5 States provided no definitions for Level II neonatal care; and 5 States provided no definitions for Level III neonatal care. Many of the definitions were the same as those used for obstetrical standards. Moreover, State standards for resource requirements (e.g., neonatal bed supply, occupancy rate, volume of deliveries, and travel time), service requirements (e.g., special laboratory tests and anesthesiology), and personnel, consultation, and facility requirements ranged from general policy statements to detailed specifications.

Not only are the definitions sparse and inadequate to characterize most existing facilities, but there is no uniform application of the standards that do exist. A 1978 HEW study of the National Guidelines for Health Planning (82) noted that "responsibilities for setting and monitoring standards related to Levels I, II, and III were unknown or not yet formalized in 30 States, " and only 4 States used licensure and certificate-of-need authorities to ensure adherence to specific standards.

"The Department of Health and Human Services (DHHS) is the new name of what was former y the Department of Health, Education, and Welfare (HEW). The new name, which reflects the transfer of most of HEW's education programs to a separate Department of Education, became 01 ficial on May 7, 1980. Both names are used in this paper.

Data Collection Problems Based on Definitional Confusions

The absence of uniform standards has complicated data collection and has made comparative statistical analysis difficult, especially when comparing cost or utilization data for different hospitals. For example, a certain facility maybe classified as a Level III hospital because it maintains long-term mechanical respirators and is staffed and equipped to provide treatment for the most seriously ill infants, even though it does not accept transports from the region and may not provide consultation, continuing education, or transport facilities for lower level hospitals within its region. The cost data for services rendered by this Level 111 hospital could not be directly compared to those of a Level 111 hospital meeting the Committee on Perinatal Health's definition for a Level 111 facility, because the two facilities would not have the same overhead for equipment and personnel. Also, utilization data would only reflect infants born at that particular hospital. On the other hand, a facility may be classified as a Level 11 hospital even though it can provide treatment for most serious neonatal illnesses and contains some equipment designated as necessary for a Level III hospital. If any comparable data are to be obtained for neonatal intensive care, the classification system must accurately reflect the treatment modes, the types of personnel, and the patient population served.

These definitional problems are evident in the major surveys undertaken to obtain data for neonatal care. Even the most basic data, such as the number of neonatal intensive care beds in the country, cannot be corroborated by the two independent surveys done to date (6,7,8,14).7

Several State surveys of NICUs have also been conducted, but these are generally limited to the data collected, and they suffer from numerous definitional ambiguities.[8]

One State has made an attempt to avoid confusion and to describe accurately services being

'These surveys of the supply of NICU beds are discussed below in the part of this case study on utilization of neonatal intensive care.

[8]The available State data are presented below in the part of this case study on util izat ion of neonatal intensive care.

provided at existing facilities by developing a unique approach to classifying NICUs. The State Advisory Committee on Perinatal Care of the Maryland Department of Health and Mental Hygiene (78) has rejected the idea of hospital classification by level of care, and instead has drafted standards for patient care situations'[1] to be dealt with at each nursery. Thus, if a hospital has the equipment and staff deemed necessary to handle a particular situation, then it can provide the services regardless of whether it qualifies as a Level I, II, or III facility. Maryland then defines an NICU as being able to provide for any neonatal patient care situation, but does not specify that the hospital maintain all the facilities recommended by the Committee on Perinatal Health. The State approved these standards for neonatal intensive care in June 1978, but the data collected have not yet been analyzed. Unfortunately, although this may represent a future model for other States, the initial reports from Maryland will be difficult to compare with reports from other States because of the lack of consistent definitions used elsewhere.

'An example of a specific patient situation might be a newborn of 37 or more weeks gestation, requiring less than 40 percent oxygen for less than 24 hours.

Summary

Because of ambiguities in commonly used definitions, we adopt in the present study a broad concept of what constitutes neonatal intensive care, i.e., we consider neonatal intensive care to be the care provided infants in Level III or Level II nurseries. Ideally, one would analyze only Level 111 nurseries. As we have seen, however, that approach would leave out a significant amount of high-technology, truly intensive care. Furthermore, it is necessary to include both Levels II and III, because data on costs, utilization, and effectiveness are often not separated by the intensity of care provided. Although neonatal intensive care generally is, and preferably should be, practiced as part of a comprehensive perinatal care system, we consider in this study only the neonatal aspects of intensive care.

INFANTS RECEIVING NEONATAL INTENSIVE CARE: FACTORS INFLUENCING PRESENT AND FUTURE DEMAND

Birthweight

Birthweight is the most important predictor of illness or death in early infancy (73). The neonatal mortality rate is, in general, directly related to the incidence and severity of prematurity. Mortality among low birthweight infants, those weighing 2,500 g or less, ranges from nearly 100 percent for newborns of birthweights less than 750 g (about 1 lb 10 OZ) to approximately 10 percent for newborns of birthweights between 2,000 to 2,500 g (4 lbs 7 oz to 5 lbs 8 oz)(28). Newborns weighing 1,500 g (3 lbs 4 OZ) or less, the very low birthweight infants, are an important subgroup, because although they represent only 1 percent of the newborn population, they account for nearly half of all infant deaths. Some 230,000 low birthweight infants are born annual] y (see table 1).

Prematurity

Conditions associated with prematurity are the most common reasons for the provision to infants of neonatal intensive care. The number one problem for premature infants, by a considerable margin, is RDS. Nearly 20 percent of all neonatal deaths are caused by this disorder, which is primarily due to the infant's being born before the lungs are ready for breathing air. Highly technological methods for keeping newborns alive while their lungs mature are the major components of neonatal intensive care.

RDS increases in incidence with the degree of prematurity. In a large study done in Norway (106), RDS was diagnosed in 5.5 percent of neonates of less than 32 weeks gestation; 2.7 percent of those of 32 to 35 weeks; and 0.3 percent of those of 36 to 38 weeks gestation. Be-

Table 1.— Birth Rate, Fertility Rate, and Total Number of Births, 1975.79

	1975	1976	1977	1978	1979a
Birth rate[b]	14.8	14.8	15.4	15.3	15.8
Fertility rate [c]	66.7	65.8	67.8	66.6	68.0
Total births.	3,144,198	3,167,788	3,326,632	3,333,279	3,473,000
2,500 g or less	231,627	229,375	234,884	236,342	NA[d]
1,500 g or less	36,297	36,449	37,602	38,752	NA[d]

[a]Provisional
bBirths/1,000 population.
cBirths/1,000 women 15 to 44 years of age
dNot available as of December 1980.

SOURCES 1975 data—National Center for Health Statistics, Monthly Vital *Statistics Reporft Final* Natality Statistics, 1975, HEW publication No (HRA) 77-t 120, vol. 25, No 10, suppl., Dec. 30, 1976
1976 **data—** National Center for Health Statistics, Monthly Vital Statistics Report, *Final Natality Statistics,* 1976, HEW publication No (HRA) 78-1120, Vol. 26, No 12 (suppl.), Mar 29, 1978
1977 data—National Center for Health Statistics, Monthly *Vital Statistics Report, Advance Report, Final Natality Statistics, 1977,* HEW publication No (PHS) 79.1120, vol. 27, No. 11, suppl. , Feb. 5, 1979.
1978 *data*— National Center for Health Statistics, Monthly *Vital Statistics Report, Advance Report, Final Natality Statistics, 7978,* HEW publication No (PHS) 80-1120, vol. 29. No. 1, suppl., Apr. 28, 1980
1979 data—National Center for Health Statistlcs. Monthly *Vital* Statistics Report, Provisional *Statistics, Annual Summary for the United States, 1979,* DHHS publication No (PHS) 81.1120, vol. 28, No 13, Nov. 13, 1980

tween 1968 and 1972, RDS-related infant mortality increased somewhat. Since 1972, however, the mortality from RDS has decreased by nearly 30 percent (90).

In addition to those with diagnosed respiratory disease, a number of premature will die without a specific disorder other than immaturity. This group accounts for over 10 percent of all neonatal deaths and often receives intensive care. Over the past 10 years, the mortality rate for the International Classification of Diseases category “immaturity, unqualified” has experienced a steady decline, from 2.69 deaths per 1,000 live births in 1968 to 1.11 deaths per 1,000 live births in 1977 (91). This change could be due in part to improved specification of diagnoses, but no study of such a trend has been identified.

Race

Since 1966, there has been a 15-percent decline in the overall incidence of low birthweight as a proportion of all births (see table 2). This decline is associated with improvements in some of the risk factors predisposing to prematurity. Major risk factors for prematurity include race and age of mother, socioeconomic level, and maternal nutrition and health practices. Race is a serious risk factor, because blacks are far more likely to have low birthweight infants than whites (see table 3). Although blacks account for only about 16 percent of all births, they account for more than one-third of the very low birthweight infants. Moreover, the rate of very low birthweight infants has not declined in recent years (see table 3). Because of the vast differences in very low birthweight rates, blacks

Table 2.–Percentage of Low and Very Low Birthweight Infants Among All Births, by Race, 1950-77

	1950	1956	1960	1966	1970	1971	1972	1973	1974	1975	1976	1977	
Percentage *of low* birth weight infants (<=2,500 g)													
Total.	7.0%1	7.23%	*7.69%*	*8.32%*	*7.89%*	*7.64%*	*7.65%*	*7.54%*	*7.39%*	*7.37%*	*7.24%*	*7.06%*	1.26%
White	5.68	5.49	5.72	5.98	5.63	5.38	5.28	5.20	5.12	5.07	4.95	4.79	–1.19
Black	1.32	1.74	1.97	2.35	2.11	2.11	2.21	2.15	2.10	2.12	2.10	2.09	–0.26
Percentage of very low birth weight infants (<=1,500 g)													
Total.	0.95%	1.08%	1.17%	1.25%	1.17%	1.14%	1.18%	1.18%	1.16%	1.13%1.15%	1.150/0	1.13°/o	–0.12%
White	0.77	0.80	0.85	0.84	0.78	0.76	0.77	0.76	0.74	0.75	0.74	0.72	–0.12
Black	0.19	0.27	0.32	0.40	0.36	0.36	0.39	0.37	0.36	0.38	0.39	0.39	–0.01

NOTE 1950$6 black birthweights reported as nonwhite

SOURCE National Center for Health Statistics, *Vital Statistics of the United States,* selected years

Table 3.— Low and Very Low Birthweight Rates, by Race, 1950-77

	1950	1956	1960	1966	1970	1971	1972	1973	1974	1975	1976	1977	1970-77 net change
Low birth weight rate[a] (<=2,500 g)													
White	65.9	64.4	67.7	72.1	68.0	65.5	64.7	63.9	62.8	62.4	61.1	59.2	– 8.8
Black	100.8	123.7	39.0	151.6	137.6	133.1	135.3	131.9	130.9	130.5	129.3	127.7	– 9.9
Very low birthweight ***rate***[b] (<= 1,500 g)													
White	8.9	9.4	10.0	10.1	9.4	9.2	9.4	9.4	9.1	9.2	9.1	8.8	– 0.6
Black	14.4	19.8	22.9	25.9	23.8	22.8	23.7	22.7	22.6	23.7	24.0	23.7	– 0.1

NOTE: 1950-66 black birthweights reported as nonwhite
aLow birthweight rate (number of infants <= 2,500 g per 1,000 live births in specified racial group.)
bVery low birthweight rate (number of Infants <= 1,500 g per 1,000 live births in specified racial groups)
SOURCE: National Center for Health Statistics, Vital Statistics of the *United States,* selected years

have a much higher neonatal mortality rate than whites. Black males have the highest infant mortality rate, with 28.3 deaths per 1,000 live births in 1975, a figure 2.3 times higher than the mortality rate for white females (90).

The black-white mortality difference is almost entirely due to the higher incidence of prematurity and low birthweight among blacks. The excess of low birthweight infants among blacks is impressive. In 1977, blacks had two to three times the rate for whites in every birthweight category under 2,500 g. On the other hand, "gram for gram" black low birthweight newborns do better than white newborns of the same birthweight, although the reasons for this are unknown. Much of the black-white difference in prematurity and low birthweight disappears when one corrects for socioeconomic factors such as education and income. In all reported studies, however, black prematurity rates are higher within every subgroup. Racial differences in mortality rates have narrowed significantly in the past few years, but have by no means disappeared.

Socioeconomic Status

Socioeconomic status is also closely related to the incidence of low birthweight. Infant mortality is higher among families in which the mother and father have an education of ***8*** years or less, and in which the family income averages less than $3,000 annually (86,123).

Birth Rate

The recent decline in the incidence of low birthweight has been offset by a "baby boom, " principally due to increased numbers of women in the childbearing ages, together with a small increase in fertility rates (see table 1). Since 1975, the birth rate has increased 6.7 percent. This has resulted in a net increase in the absolute number of low and very low birthweight infants born each year (see table 1), Clearly, any increases in the number of very low birthweight infants will expand the number of newborns receiving neonatal intensive care. The Census Bureau projects an 8-percent increase in the number of women in the childbearing ages between 1979 and 1985 (93). Thus, increased demand for intensive newborn care can be expected.

Congenital Anomalies

Not all neonatal problems requiring intensive care are due to prematurity or low birthweight. Other risk factors can increase the number of problems that infants will have, whether or not they are premature. Often, infants suffering severe congenital anomalies are born at term. These anomalies are physical or metabolic abnormalities that include anencephalus (no brain), spina bifida, and other serious problems affecting the major body systems. Together, they account for nearly ***20*** percent of infant deaths (93).

Congenital heart diseases present the largest group of congenital anomalies, accounting for over 5 percent of all neonatal deaths in 1977 (87). The development of surgical techniques for curing or ameliorating many previously fatal congenital heart defects has revolutionized treatment of these conditions over the past 10 to 15 years. The infants on whom surgery is performed are generally cared for in NICUS both preoperatively and postoperatively. The neonatal mortality rate for congenital anomalies has also shown a steady decline over the past decade, from 2.14 deaths per 1,000 live births in 1968 (85) to 1.79 deaths per 1,000 live births in 1977 (87).

Other serious problems treated in neonatal intensive care units include diarrhea and malabsorption diseases, meningitis, hemorrhagic disease of the newborn, idiopathic jaundice of the newborn, and septicemia (blood poisoning). Certain risk factors associated with many of these neonatal problems have been improving in recent years, although a few have been getting worse.

The identification of risk factors associated with neonatal mortality and morbidity has led to interest in programs aimed at preventing newborn disease. Some risk factors, such as maternal socioeconomic status, require complex and costly interventions with uncertain benefits, and are addressed through welfare, education, and job programs. Other risk factors can be traced to specific maternal illnesses or behavior, or to events occurring during the prenatal period. For example, smoking and alcohol and drug abuse can cause intrauterine growth retardation and a number of necrologic and metabolic disorders. These factors have direct causal links with certain newborn problems and might allow for targeted interventions with reasonably predictable benefits.

Because so many of the problems of the newborn are associated with maternal factors that can be detected during pregnancy by routine prenatal care and the use of specialized diagnostic procedures, about two-thirds of infants who will require special care can be identified before birth (4). Unfortunately, such screening is costly and has high false-positive and false-negative rates. In other words, some high-risk women will deliver normal infants, while some low-risk women will produce sick ones.

Maternal Age

The incidence of abnormal birth can be directly related to maternal age. Mothers over the age of 35 have an increased risk of having fetuses with genetic malformations and of experiencing fetal death in utero (84). A strong correlation exists between pregnancies in older women and the incidence of Down's syndrome (mongolism) (12). Older mothers are also more likely to produce a low birthweight baby, but they contribute an insignificant proportion of this risk group. Between 1950 and 1977, birth rates for mothers aged 35 to 39 have declined by two-thirds, from a rate of 60 per 1,000 women in that age group to less than 20 per 1,000. Birth rates for mothers aged 40 to 45 have also declined, from 15 per 1,000 to less than 3 per 1,000 (92).

Teenage pregnancy also produces infants at high risk. Very young mothers commonly have hypertension of pregnancy, premature labor, or a small pelvis contributing to birth injury (4). Mothers under 15 years old have the highest risk of any group for producing a low birthweight baby (84). This group of mothers remains small, with very low birth rates, and accounts for only one-third of 1 percent of births (86). Among slightly older teenagers 15 to 17 years old, the number of births rose by over 20 percent between 1966 and 1975 (86), but has since fallen by nearly 11 percent, to pre-1970 levels.

Prenatal Care

Several studies have tried to assess the role of prenatal medical care in determining the outcome of pregnancy (42,50). unfortunately, it proves difficult to separate prenatal care from the other factors that influence outcomes. A recent analysis based on relatively old ***(1968)*** data for New York City suggested that if prenatal care exerts any effect on infant mortality, it is likely that it does so by reducing the incidence of low birthweight newborns (50), It has also been reported that the greatest risk of having a low birthweight baby comes from pregnancies with no prenatal medical care (42).

Only a small number of pregnancies in the United States are *now* at risk due to inadequate prenatal care, and the proportion of pregnancies with inadequate prenatal care has been declining in recent years. In States reporting to the National Center for Health Statistics, the percentage of pregnancies with late prenatal care[10] or no prenatal care fell from 8.1 to 6.0 percent between 1969 and 1975 (89). Much of the decline represented major increases in access to prenatal care by blacks, among whom inadequate prenatal care fell from 18.2 percent in **1969** to 10.5 percent in 1975 (89).

Medical Practices

Finally, risks have also been associated with medical practices such as electronic fetal monitoring (11), amniocentesis, cesarean section, and induced labor (77), all of which are becoming more common. Between 1971 and 1975, the cesarean section rate in the United States nearly tripled, from 5.5 percent of births to 15.2 percent (100). In California alone, 15.4 percent of births in 1977 were delivered by cesarean section, a greater than threefold increase from the 5.1 percent rate in **1965 (131).** The aforementioned medical practices could result in more premature births, but it is not yet clear whether they will increase or decrease the need for intensive care in the newborn period. If early delivery after signs of fetal distress does indeed reduce the incidence of complications such as asphyxia, less care after birth might be necessary. This could partially offset the increased demand likely to result from the current "baby boom. " Studies on the impact of fetal monitoring, however, do not appear to justify any hope for a dramatic reduction in the demand for newborn intensive care. The main determinant of the demand for intensive newborn care will probably be the duration of the present increase in the birth rate and the total number of births.

[10] Care initiated in the third trimester of pregnancy

UTILIZATION OF NEONATAL INTENSIVE CARE

No national data that describe the amount of newborn intensive care now being provided in the United States are available. Rough estimates can be computed, however, by extrapolating from the data that are available. The estimates are necessarily rough because of definitional inconsistencies in the data that are available and small sample sizes on which the data are based. As noted earlier, the definition of what constitutes an NICU varies from study to study, and reports often fail to separate units by level of care. More importantly, however, the existing data are based on limited experience, often in small geographic areas with small or restricted population samples, and case-mix severity is not controlled.

We calculated the following estimates of neonatal intensive care availability and use in the United States based on utilization data available in the literature and submitted by individual nurseries:

- NICU admission rates: 6 percent of all live births go to intensive care (about 200,000 admissions annually, range 3.8 to 8.9 percent of all births).
- Estimated ALOS: 8 to 18 days per patient (mean 13).
- Estimated total patient days: 2.6 million.
- Number of hospitals with NICUs: approximately 600.
- Number of intensive care beds (Levels II and III): 7,500 (approximately 2.3 beds per 1,000 live births).

The data we used and the manner in which we arrived at these estimates are discussed in the sections below.

NICU Admission Rates

Admission rates for NICUs vary according to availability of facilities, staffing capabilities, physician referral patterns, and risk factors present in different areas. Data from three large population-based studies and reports from five individual neonatal centers are summarized in table 4.

The range of NICU admission rates across the three population-based studies shown in table 4 is substantial and is probably part real and part an artifact of reporting procedures. The New York City area has a number of factors associated with high-risk pregnancies: a large black population, high prematurity rates, and a high incidence of inadequate prenatal care. Because of reporting vagaries, the figure reported for New York City could be as low as 7.5 percent, still considerably above the figures for Ohio and California. Less than 4 percent of Ohio's births and just under 6 percent of California's births received intensive care in the newborn period. These figures reflect Ohio and California's lower rates of prematurity and other risk factors (13). When data for all three regions are combined, the weighted average admission rate is about 5.9 percent (see table 4). The sources of this figure are quite disparate. However, the fact that it is based on over **20** percent of all births in the United States makes **6** percent seem a reasonable estimate for the country as a whole. Level 111 referral hospitals consistently reported higher NICU admission rates than the large population surveys, with rates ranging from less than 10 percent to more than **20** percent of all births (see table 4). These hospitals have relatively high-risk inborn populations because they serve as regional per]. natal referral centers.

These figures only reflect current practice, and they are not necessarily indicative of ideal patterns of care. It is not possible to conclude whether or not the present levels of utilization are appropriate, because the limitations of currently available data make it impossible to analyze the reasons for the wide discrepancy in utilization. The American Academy of Pediatrics (5) has estimated that 9 to 11 percent of all live births would require special care—2 to 4 percent at the intensive level and 7 percent at the intermediate and continuing care levels. This figure has been widely cited even though it was simply a consensus approximation by members of the Manpower Subcommittee of the Academy's Committee on the Fetus and Newborn. Clearly, admission rates will vary with the incidence of very low birthweight infants in a population, but it is not yet reasonable to attempt to define precise, ideal utilization rates for different frequencies of prematurity y.

Length of Stay

Estimating ALOS is even more difficult than estimating NICU admissions. In addition to the problems associated with differential risk factors and a lack of comparable definitions, extensive transfers of infants in and out of hospitals and among beds and units of different intensity levels causes double counting of the same infants. The literature and our estimate may therefore underestimate ALOS and, correspondingly, overestimate admission rates.

Table 4.—NICU Admission Rates, 1975-78

Region or hospital and year[a]	Births	NICU admissions	Percentage of births
Large surveys			
Southern District New York State, 1977 (76)	131,834	11,128	8.4%
California, 1977 (24)	347,426	20,551	5.9
Ohio, 1977 (103)	160,850	6,058	3.8
Total	640,110	37,737	5.9%
Individual centers[b]			
UCSF Medical Center, 1976-77 (99)	1,921	276	14.4 "/0
University of Washington, 1978 (60)	1,500	317	21.0
Bellevue Hospital, 1975-76 (43)	612	88	14.4
Brooklyn Hospital, 1975 (43)	2,485	263	10.6
Milton S. Hershey Medical Center, 1977-78 (55)	1,350	300	22.2

aNumbers in parentheses refer to references in the list that appears at the end of this case study
bNICU admissions include in born babies only (no transfers)

On the basis of the available data collected from individual NICUS (25,54,55,60,76,94,97, 98,103,122), and the Children's Hospitals Automated Medical Programs (29), we estimated an ALOS of 8 to 18 days (mean, 13 days) per patient in Level II and 111 nurseries combined. Because of the problem of double counting of transferred infants, however, utilization of NICUS can better be expressed in terms of total patient days, number of beds, and occupancy rates (as shown below).

To summarize, ALOS varies widely from one State to another, among hospitals, by birthweight, and by diagnosis. Data from the abstracting service for children's hospitals shown in table 5 demonstrate the variation in ALOS by diagnosis. Data for different NICUS are summarized in table ***6;*** those for different regions are summarized in table 7.

Table 5.—Average Length of Stay (ALOS) in Children's Hospitals, by Diagnosis, 1976-77

	ALOS (in days)	
Diagnosis	1976	1977
HMD/RDS	20.3	18.5
Immaturity	29.8	29.6
Asphyxia	14.2	15.9

SOURCE: Data in this table were supplied by the Children's Hospitals Auto. mated Medical Programs (CHAMP), Columbus, Ohio (29) Any analysis, interpretation, or conclusion based on these data or any other data cited elsewhere in this study as having been supplied by CHAMP is solely that of the Health Policy Program CHAMP specifically disclaims responsibility for any such analysis, Interpretation, or conclusion.

Total Days of Care

The total number of days of intensive care in NICUs for the United States can be approximated by multiplying estimated NICU admissions by estimated ALOS. Applying an estimated NICU admission rate of ***6*** percent to the number of live births registered in the United

Table 6.—Average Length of Stay (ALOS), by Hospital

Hospital and year[a]	Admissions	Patient days	ALOS[b] (in days)
University of Washington Hospital, Seattle, 1978 (60)	461	9,128	19.8[c]
Children's Orthopedic Hospital, Seattle, 1978 (60)	407	7,326	18.0
Hospital for Sick Children, Toronto, Canada, 1978 (122)[d]	.	—	17.oe
UCSF Medical Center, 1978 (98)	1,185	—	14.8
Milton S. Hershey Medical Center, Pennsylvania State University, 1977 (55)	527	8,485	16.1
Milton S. Hershey Medical Center, 1978 (55)	475	9,358	19.7

aNumbers in parentheses refer to references in the list that appears at the end of this case study
bTotal stay for Levels II and Ill combined
cSurvivors, 22 days (83.7%), nonsurvivors, 85 days (16.3%)
dSwyer reports ALOS was similar at McMaster University Medical Center and Emory University in Canada for the same Year
eALOS for infants admitted directly to Level II is 7 days

Table 7.—Average Length of Stay (ALOS), by Region

Region and year[a]	Admissions	Discharges	Patient days	ALOS (in days)
Southern District of New York State, 1977 (76)	–	9,867	170,233	17.3[b] 15.3[c]
Ohio, 1978 (103)	6,058	—	129,013	21.3
California, 1977 (26)	—	20,551	178,744	8.7
California, 1972-73 (54)	6,863	—	—	10.8[d] 11 .3[e]
Massachusetts, 1976 (94)	—	—	—	12.9[d]
Pennsylvania, 1977-78 (97)	—	—	—	11.8

aNumbers in parentheses refer to references in the list that appears at the end of this case study
bBased on reported discharges
cBased on the larger of admissions of discharges where discrepancies exist n hospital reports to the United Hospital Fund of Greater New York
‘Level III
‘Level II

States for 1978, 3,329,000 (79) yields as the total number of newborns requiring intensive care in 1978 approximately 200,000. If one uses an approximate ALOS of 13 days, total patient days (admissions x ALOS) would be 200,000 X 13 = 2,600,000. This total, 2,600,000 days, would represent approximately 0.7 percent of the U.S. total of hospital days for 1978 (380,152,083 total hospital days) (32).

Supply of NICU Beds

A limited number of surveys of NICU facilities are currently available (see table 8). The results are contradictory and are difficult to reconcile.

Table 8.—Supply of NICUs and Beds in the United States, 1976-78

	AHA	MFIS	Ross
1976: 6,500 *hospitals reporting*			
Number of hospitals with premature nursery facilities	1,923	2,017	—
Number of hospitals with NICUS. . .	529	540	–
Number of hospital beds used for neonatal intensive care,.	6,602	6,668	—
1977: 6,495 *hospitals reporting*			
Number of hospitals with premature nursery facilities	1,821	2,014	—
Number of hospitals with NICUS. . .	591	655	–
Number of hospital beds used for neonatal intensive care.	7,553	7,792	—
1978: 6,321 *hospitals reporting*			
Number of hospitals with premature nursery facilities	1,726	NA	—
Number of hospitals with NICUS. . .	448	NA	259
Number of hospital beds used for neonatal intensive care.	6,252	NA	7,387

NA = not available

SOURCES 1976 data: AHA (7), MFIS (79)
1977 data AHA (8), MFIS (79).
1978 data: AHA (9), Ross (14).

The American Hospital Association's (AHA) Annual Survey of Hospitals counted NICUs and beds for the first time in 1976, and reported the results in 1977 (7). The 1977 (8) and 1978 (9) surveys have now been published, as well. The apparent increase and decline in NICU supply over those 3 years cannot be explained by AHA staff with confidence, although the pattern may simply reflect the vagaries of the first years of reporting a new survey item.

The AHA figures reflect all hospitals in the United States except the 200-plus institutions that are not registered with AHA. In its Master Facility Inventory Survey (MFIS), the National Center for Health Statistics uses AHA survey results and adds an estimate for the hospitals that are not registered (79).

AHA has not yet separated NICUs into different levels, although it had intended to do so in the most recent survey, Thus, AHA and MFIS figures should include all NICUs and all NICU beds at every level of intensity.

Ross Laboratories, which surveyed only Level 111 regional referral centers, counted virtually the same number of NICU beds as AHA in only half the number of hospitals (14). Although counting beds is complicated by differences among beds in use, licensed beds, and specially designated NICU beds, Ross tried to report the standard number of infant positions normally accommodated in the neonatal units surveyed. A 1980 update of this survey should be available soon.

Since the discrepancies among the reports show no consistent pattern (see table 8), the relationship between the Ross data and AHA and MFIS reports cannot be determined. Moreover, none of the published national surveys has publicly identified individual hospitals, making it impossible to cross-check the results directly.

Our estimate of 7,500 beds was reached by combining the results of the bed surveys (see table 9) with the estimated number of days of care being provided. That is, our estimate of 2.6 million patient days would require 7,500 beds at a 95-percent occupancy rate ([2,600,000/(365 x 7,500)] = 0.95). Our estimate of 7,500 beds is, in fact, a conservative figure. If the Ross data accurately portray the number of beds in Level 111 hospitals alone, the national total for both Levels II and III could be closer to 14,000 beds.

Table 9.—Number of NICU Beds in the United States

Survey and year[a]	Number of hospitals with NICU	Number of beds			Beds/hospital
		Maximum care	Intermediate care	Total	
California					
RoSS, 1978 (14)	28	330	394	724	25.9
MCH, 1976 (53).	23 (of above)	192	221	413	18.0
OSHP, 1977 (25). ., ...	23 (of above)	—	—	467	20.3
MCH, 1976 (53).	43	236	308	544	12.7
OSHP, 1977 (25).	54	—	—	697	12.9
Ohio					
Ross, 1978 (14)	9	142	202	344	38.2
SDH, 1978(103)).	17	—	—	472	27.8
Massachusetts					
Ross, 1978 (14)	6	65	47	112	18.7
SHP, 1979(94)	8	95	69	164	20.5
New *York*					
Ross, 1978 (14)	21 (15-NYC area)	292	468	760	36.2
UHF/NY, 1978 (75)	27 (NYC area)	—	—	505	18.7
UHF/NY, 1978 (75)	14 (of 15 above)	—	—	392	28.0
Washington					
Ross, 1978 (14)	4	52	38	90	22.5
UW, 1978 (60)	6	71	39	110	18.3

aNumbers in parentheses refer to references in the list that appears at the end of thls case study

COSTS OF NEONATAL INTENSIVE CARE

The costs of neonatal intensive care are great. Among patients with high cost hospitalization ($4,000 or more in 1 year) studied by Schroeder, et al. (112), neonatal cases were by far the most expensive, averaging over ***$20,000*** each. In fact, neonatal costs were higher than those for neoplastic and circulatory diseases, two of the most expensive adult services. They were similar to the total cost of end-stage renal disease and coronary bypass surgery, both of which require specific costly medical technology. Various reports of neonatal intensive care costs range from $1,800 to $40,000 per patient. We estimate average expenditures in 1978 to be about $8,000 per case. In the United States as a whole, this amounts to approximately $1.5 billion (19,98).

Findings and Limitations of Cost Data

Cost data are plagued with even greater problems than are utilization and supply data. NICUS are often not separate cost centers in hospital reports, but are mingled with other intensive care or pediatric services. Even when the units are identifiable cost centers, the costs that generally are reported exclude so-called "ancillary services" such as laboratory tests, X-rays, and physician fees. Since diagnostic and therapeutic services are a major part of the total costs of caring for neonatal patients, such figures greatly underestimate per capita costs. Total costs per patient are not readily accessible except from the limited number of special studies that have been undertaken (see table 10). In order to compare nurseries studied at different times, we have updated many of the figures to 1978 dollars, **as** specified.

Many of the data report hospital charges that may not in any way reflect actual costs. Hospital charges allocate overhead and other costs not directly attributable to an individual patient according to reimbursement practices and overall institutional revenue targets.[11] Moreover, most States do not require uniform accounting, and comparability among hospitals is limited as a result.

Additional problems arise because costs for

[11] 'See section below on reimbursement for neonatal intensive care.

Table 10.—Summary of Cost Studies on NICUs

Study[a]/year/population	Characteristics of data	Average cost per day	Average cost updated to 1978	Total cost per patient
Cotton, Vanderbilt University, Term. (33) • 1976, 3 months • S & NS	1, 2 4—No information if the charges cover both S & NS. Also all but 8.3% of total was spent on S. 4— Nothing on cost/charges per patient care or ALOS for S.	$700 NS	$832 NS	$5,691 S $2,966 NS
Kaufman & Shepard, Tufts New England Medical Center, Mass. (66) . 1978 • Level I I I services	1, 2	$345 III	$345 III	—
Kaufman & Shepard, Johns Hopkins, Md. (66) • 1978	2	$188 I $200 II $340 III	$188 I $200 II $340 III	—
Kaufman & Shepard, Women & Infants Hospital, R.I. (66) . 1978	1	$74 I $130 II $175 III	$74 I $130 II $175 III	— — —
Hawes, 19 tertiary NICUs & 1 community (Ii) hospital, Cal if. (54) • 1973 • 54'io of 6,863 admissions were transfers	1, 3a, 3b 4—Total costs/charges will be underestimated since over 50% of infants were transferred and some 12 of the 20 hospitals are returning babies to community hospitals for convalescent care. 4—Reported from 11 hospitals. No information on what it covers.	$123 II $198 III	$24511, a b $394 III, a b	$1,390 II (ALOS = 11.3 days) $2,138 III (A LOS = 10.8 days) $5,1 78= average total cost, b
Kaufman & Shepard, Model Budgets (64) • 1977	3a 4–Based on Swyer's (121) estimate of total patient days (45/1,000 live births need Level II; 45/1,000 need Level III; 6 day ALOS). 4— Includes obstetric and neonatal services.	$125 II (80% occ.) $213 III (83%occ.)	$15511, a $266 III, a	— —
McCarthy, Children's Hospital, Denver, Colo. (80) • 1976, 4-month period • 84% S & 16% NS • All transport infants	1, 3b 4—Charges include transport fees.	$338 S (mean) $607 NS (mean)	$442 S, b $793 NS, b	— —
Kaufman & Shepard, Boston Hospital for Women, Mass. (65) • 1977 • 10 infants: 750-999 g • 40% S & 60% NS	4—Costs allocated based on accounting costs and services rendered. Costs cover MD fees, ancillary services and overhead,	$579 S & NS	$628	$14.654-$40.752 S (62-110 days S) $0-$7,594 NS
Meier, University of Washington NICU (83) • 1978 • Infants with HMD • 12 of 31 infants were transfers	1	$308 S & NS "	$308	$14,190 (46 days)
Children's Hospital Medical Center of Northern California (30) . 1976	3a, 3b, 4— No information on number of infants or ALOS.	$243 [$430 charge]	$361 a & b	—

Table 10.—Summary of Cost Studies on NICUs—Continued

Study[a]/year/population	Characteristics of data	Average cost per day	Average cost updated to 1978	Total cost per patient
Pomerance, NICU at Cedars-Sinai Medical Center (102) . Adjusted to 1976 . Infants 1,000 g • 40% S & 60% NS	1, 3b 4— Used 940/0 of collected hospital charges as actual cost of care.	$825 NS, b $450 S, b	$1,078 NS, b $588 S, b	$14,236 (17 days) $40,287 (89 days)
Shannon, Massachusetts General NICU (1 14) • 1974 . Infants without RDS • 70°/0 S & 300/0 NS • 330/0 transfers	1,2	$299 S $720 NS	$436 $1,050	$8,842 S (29.6 days) $2,448 NS (3.4 days)
Phibbs, UCSF, NICU (98) • 1978 (over 30-month period) . by S & NS, birth weight, diagnosis & treatment, inborn v. outborn • sample = 1,185 infants	1	$545	—	$8,069 (ALOS = 16 days) S = $7,620 NS = $11,624 <= 1,500g = $16,684
Children's Hospital Automated Medical Programs (29) . 1975—12,770 Infants . 1976—14,645 infants . 1977—1 7,714 infants	1	1975–$229 1976—$291 1977–$340	$298 $346 $369	1975—$3,1 77 (ALOS = 14.8 days) 1976—$4,203 (ALOS = 15 days) 1977—$5,283 (ALOS = 15 days)

aNumbers in parentheses refer to references in the list that appears at the end of this case study

KEY
S = survivors
NS = nonsurvivors
ALOS = average length of stay
HMD = hyaline membrane disease
RDS = respiratory distress syndrome

1 = study reports charges rather than costs
2 = no Information on what cost/charges cover
3a = costs/charges do not include ancillaries
3b = costs/charges do not include physician fees
4 = other characteristics

a = Ancillaries = 15%
b = M D fees = 100,.
I = Level I bed
II = Level II bed
III = Level III bed

different levels of care and diagnoses are typically aggregated as a single composite figure. Together with the frequent need to transfer patients among hospitals with different levels of care, this nearly precludes collecting total costs per patient. Patterns of practice and case mix are not reflected in existing systems for collecting or reporting financial data.

Costs by Birthweight, Diagnosis, and Outcome

Phibbs, et al. (98) analyzed total charges billed to all NICU patients at the University of California, San Francisco (UCSF), over a 30-month period through the end of 1978. They found the average charge for the whole sample (N = 1,185) to be $8,069, the average charge to produce a survivor to be $9,089, the average daily charge to be $545, and the ALOS to be 16 days.

Their analysis emphasizes the great variation in costs of care among patients. All admissions were classified by birthweight, diagnosis and treatment, outcome (survival v. nonsurvival), and inborn v. outborn. Their results show that average costs increased as assisted ventilation was employed, as surgical procedures were used, and as birthweight fell (see tables 11, 12, and 13).

Table 11 .—Cost by Birthweight Group—All Patients

Birth weight group	Average cost	Cost to produce a survivor[a]
<= 1,000 g	$19,213	$31,621
1,001 to 1,500 g . . .	15,204	18,659
1,501 to 2,000 g . . .	9,516	10,140
2,001 to 2,500 g . . .	5,908	6,499
2,501 to 3,000 g . . .	5,445	5,874
>3,001 g . ,	5,649	6,157

aCost to produce a survivor = total cost/number of survivors

SOURCES C S Phibbs, et al Analysis of Factors Associated With Costs of Neonatal Intensive Care 1980 (98), and R H Phibbs, UCSF unpublished data. 1979 (99)

Table 12.—Cost by Birthweight Group—Inborn[a]

Birthweight group	Average cost	Cost to produce a survivor[b]
<= 1,000 g	*$22,508*	*$46,340*
1,001 to 1,500 g	15,457	17,630
1,501 to 2,000 g	7,645	8,038
2,001 to 2,500 g	4,307	4,397
2,501 to 3,000 g	3,378	3,626
>=3,001 g	2,123	2,138

aUniversity of California, San Francisco, 1976-78.
bCost to produce a survivor = total cost/number of survivors

SOURCES: C S. Phibbs, et al , "Anlalysis of Factors Associated With Costs of Neonatal Intensive Cale," 1980 (98); and R H Phibbs, UCSF, unpublished data, 1979 (99)

The Phibbs, et al., study (98) also demonstrated that neonatal intensive care is often used for relatively brief periods to observe and stabilize high-risk patients. Nearly one-half of the infants in their study were in the category "normal birthweight, never requiring assisted ventilation or surgery. " That group of infants was relatively low cost, averaging $2,190 per case and collectively accounting for only 13 percent of the total charges. Another group, the 24 percent of infants with the greatest medical and surgical complications, represented nearly 60 percent of the total charges.

Additional cost studies have reported similar relationships: 1) total costs for survivors are higher than for nonsurvivors; 2) as birthweights decrease, costs increase; and 3) total costs increase with complications such as HMD (see table 10).

Meier (83) analyzed the in-hospital costs of treating HMD in the NICU at the University of Washington Hospital between 1977 and 1978. For survivors, the average cost per patient day was $435, compared to $1,050 a day for nonsurvivors. The cost per day among survivors did not differ greatly within the disease categories, but total costs for treating surviving infants were strongly correlated with the length of hospitalization. Thus, the mean cost per surviving infant ranged from $8,560 for those in the mild disease category to $35,210 for those with severe disease. Shannon, et al. (114) also studied the costs of treating RDS at the Massachusetts General Hospital in 1974. Shannon found that for survivors, with an average of ***29.6*** days of intensive care, the total cost was $8,842 in 1974 dollars. For nonsurvivors, averaging 3.4 days of intensive care, the total cost was $2,448. Expressed as 1978 dollars, these figures would be $12,890 **and** $3,569, respectively.

Support services, personnel, and other resources are heavily consumed in the earliest stages of neonatal intensive care; the later days for observation and recovery require less intensive care. For example, one study noted that the first few days of neonatal intensive care require a nurse-to-infant care ratio of 1:1 or 1:2, plus many ancillary procedures (80). During recovery days, the nurse-to-infant care ratio was about 1:4. Fewer daily services and tests were performed. The high mean charge per day for nonsurvivors reflects the early intensive care days without the averaging effect of the survivors' recovery days (80). This finding that cost per day for nonsurvivors is almost twice as high as for survivors has been demonstrated in

Table 13.—Average Cost by Diagnostic Group and Outcome

Diagnostic group	Total sample: All patients	Total sample: Inborn	Total sample: Outborn	Survivors: Inborn	Survivors: Outborn	Non survivors: Inborn	Non survivors: Outborn
Primary medical with major surgical complications	$23,952	$38,844	$19,874	$36,540	$14,096	$12,639	$37,522
Primary medical	5,822	5,038	7,936	5,017	7,994	7,114	4,985
Noncardiac anomaly, treated medically	4,804	3,051	5,839	4,053	5,912	2,186	7,541
Cardiac, treated medically	3,151	5,259	2,934	6,946	3,109	1,297	1,761
Primary surgery—not cardiac or anomaly	10,207	16,786	9,195	16,786	9,195	–	–
Noncardiac anomaly, treated surgically	21,077	26,020	20,273	29,871	20,117	2,912	18,594
Cardiac treated surgically	17,227	15,848	17,320	15,501	16,897	—	10,547
Average cost	$ 8,069	$ 5,952	$10,872	$ 5,824	$10,332	$ 7,870	$13,357

aExcept patent ductus arteriosus

SOURCES : C. S Phibbs, et al , "Analysis of Factors Associated With Costs of Neonatal Intensive Care," 1980 (98), and R H Phibbs, UCSF, unpublished data, 1979 (99) additional studies (65,102). Other studies comparing neonatal intensive care costs to birthweight demonstrate a clear relationship: As birthweight decreases, cost increases.

Total Costs and Charges

A model NICU budget in the 1976 report of the Committee on Perinatal Health (32) used 1974 financial data from hospitals in the mid-Atlantic region. In the absence of alternatives, this budget has been the main planning tool for hospitals and policy makers alike. The budget has been criticized, though, for its low overhead and unrealistic physician salaries *(64).*

An updated model NICU budget prepared by Kaufman and Shepard *(64)* showed that the average costs per patient day would be $213.40 at 83-percent occupancy for a Level III NICU. A Level II unit at 80-percent occupancy would have average daily per patient day costs of *$124.78.* These figures do not include ancillary costs and are at least $50 less per patient day than reports in the literature from actual nurseries. Table 10 displays existing studies on costs for NICUs by level of care and outcome, birthweight, and diagnosis. The following discussion summarizes the findings from these cost studies.

Data collected in 1976 by the Massachusetts Rate Setting Commission *(64)* show total costs ranging between *$80* and $488 per patient day for eight Level III NICUs in Massachusetts. The wide range was due to a number of factors, including case mix, occupancy levels, accounting methods, size, specialization, and the mix of intensive and less intensive beds. For example, the mean cost of NICUs with intensive beds only was *$287* per patient day, while NICUs with multiple levels of care averaged $133 per patient day, a figure much closer to the updated model budget estimate.

Hawes (54) collected charge data for patients in California NICUs in 1973. In that study, estimated daily charges averaged $198 for Level III units and $123 for Level 11 units, or an average of $160 per day for a newborn staying an equal number of days at each level. Updated to 1978 dollars, this would be equal to $255 per day on average, or $315 for Level III beds and $196 for Level II beds *(54).* (Adjusting for physician fees and ancillary services adds approximately *25* percent to these figures.)

As is evident from these existing studies, costs and charges vary by accounting methods, case mix, and level of care provided. Given the wide range of costs and charges evident in the data, it is difficult to estimate total costs with confidence. Each of the studies described above has its limitations, as summarized in table 10. The most comprehensive and recent data are those from the study by Phibbs, et al. *(98).* Based on their work, we expect that total costs will average about $8,000 (in *1978* dollars) for the wide range of patients in a Level 111 full-service nursery that has both inborn and transported-in infants. **As** those authors point out, newborns with different diagnoses and birthweights will have widely varying costs, and the particular case mix must be taken into account in estimating total costs for a specific nursery.

Using the figures reported by Phibbs, et al. (98) for purposes of illustration, we can make a crude estimate that about $1.5 billion was spent on neonatal intensive care in 1978 (see table 14). Their estimate of mean charge per case was chosen because it represents a large, diverse, and virtually complete sample of patients. The authors took great care to track down all charges, including physician fees. The UCSF estimate *(98)* may or may not be representative of other areas of the country. However, since neonatal intensive care is available primarily in urban centers, the figures for San Francisco should not be unreasonably high. For example, the UCSF estimate of mean charges for outborn patients transported in was $10,872, remarkably close to the $10,513 reported for patients transported to The Children's Hospital in Denver, Colo. (80).

Reimbursement for Neonatal Intensive Care

The diversity and complexity of hospital billing and third-party reimbursement practices further complicate the attempt to measure the costs of neonatal intensive care. One particular problem is the degree to which the present sys-

Table 14.—Alternative Estimates of Total Annual Costs for Neonatal Intensive Care, 1978

1. Number of births (3,300,000)	x	Percentage of all births admitted to NICUS (0.06)			x	Mean cost/ Patient ($8,000)	=	Total cost $1.58 billion (1978 dollars)
2. Number of Level III beds reported by Ross Laboratories (7,387)	x	Estimated occupancy rate (0.90)	x	Days/year (365)	x	Mean cost/day ($545)	=	Total cost $1.3 billion (1978 dollars)

SOURCE Text and previous tables

tern encourages cross-subsidies, so that costs properly attributable to one patient may be borne by other patients. Hospital charges for neonatal intensive care are often not fully reimbursed by medicaid or by insurance plans that pay only for "allowable" costs. This situation creates incentives for hospitals to adjust charges to cover their expenditures by cross-subsidizing among payers. Moreover, because it is difficult to adjust charges continuously with varying levels of care, expected revenues often are below costs at the beginning of a stay and exceed costs at the end, allowing for cross-subsidies based on variations in the length of stay. Problems created by cross-subsidies include encouraging NICU admission of infants with less serious problems and extending stays after treatment when it would be adequate to continue care in a lower level and less costly setting.

Common reimbursement methods used by individual hospitals in five Eastern States, all of which have State ratesetting programs, illustrate the following variations: 1) units may not be the same as cost centers recorded in the hospital's accounting scheme; 2) levels of care are often not differentiated according to cost; 3) intensive care for adults and newborns are sometimes grouped together for cost purposes; and 4) services included in the per diem rate vary (66). Table 15 summarizes the examples of neonatal intensive care reimbursement systems.

These reimbursement methods often result in a less expensive level of neonatal care's cross-subsidizing other more expensive care. The major villain in cross-subsidization, as far as hospitals are concerned, is medicaid, because medicaid pays a fixed amount per day for any type of hospital care in some States, and reimburses costs rather than charges in other States, even when the State formula pays separately for intensive care. It is difficult to identify which is the chicken and which is the egg in the cycle. Hospitals adjust charges to cover total expenditures, medicaid and other cost-payers then pay at the level of allowable costs, and hospitals raise charges even more to cover the difference. Neonatal intensive care, because of its high-cost nature, presents a telling picture of hospital practices in maximizing reimbursement. In the limited number of studies in which costs and charges could be compared, costs represented about 68 percent of the charges (27,55).

A limited number of studies have been conducted on the sources of payment. In a 1978 study, McCarthy, et al. (80), examined hospital charges (excluding physician fees) by source of payment for 174 admissions to Denver's Children's Hospital during 4 months in 1976. As described earlier, the amount paid was dependent on the type of insurance coverage. Of the accounts closed within 2 years of discharge from the NICU, third-party payers paid 85 percent of the bills, direct or individual payers paid 4 percent, and 11 percent was uncollectible. Infants covered by medicaid (15 percent) were responsible for 51 percent of the uncollectible or writeoffs (see table 16).

Kaufman and Shepard (65) compared their own estimates of the cost per day for 10 low birthweight infants to hospital charges and to expected revenues (see fig. 1). Blue Cross paid about 80 percent of charges. Medicaid, accounting for 20 percent of the hospital billings, paid a flat per diem rate that amounted to about one-half of the hospital's charges. Uncollectible (including discounts, bad debts, and regulated fee schedules) were primarily among charge-payers and amounted to 14 percent of the total charges, a figure very close to that reported by McCarthy, et al. Blue Cross reimbursement and

Table 15.—Examples of Existing Systems of Reimbursement of Neonatal Intensive Care

Hospitals	Cost centers	Hosapital charges	Commercial or private Insurance	Blue Cross	Medicaid	Self-pay patients
Massachusetts Boston Hospital for Women; Tufts New England Medical Center; Memorial Hospital, Worcester	NIC as distinct from other units	Hospitals have flexibility to set charges	Pay directly for care	Contracts rate with individual hospitals depending on ratio of costs to charges. Can set specific unit of care	Uniform per diem rate for an services provided to all patients	Pay directly for care
New York All hospitals	No distinction of units	Same daily charge for all types of inpatient care, computed yearly for each hospital	All inclusive per diem. Exclusive of care of well newborns —reimbursed at 1/3 the hospital per diem	All inclusive per diem. Exclusion for care of well newborns—reimbursed at 1/3 the hospital per diem	All inclusive per diem. Exclusion for care of well newborns— reimbursed at 1/3 the hospital per diem	Pay directly for care
Connecticut Yale-New Haven Hospital	NIC as distinct from other units, Yet, this is not required in State reporting forms	Two charges generally: sick newborns and well newborns. Yale-New Haven sets one level for all infant special care	No information	95%. of charges	Retrospective and based on costs	Pay directly for care
Maryland Johns Hopkins Hospital, others in passing	NIC can be a separate cost center, but not required. Hopkins considers NICU separately	Cost Review Commission sets average rate for each of three levels of neonatal Intensive care. Hospitals can adjust rates to cover costs	No information	Set by Cost Review Commission	Set by Cost Review Commission	Pay directly for care
Rhode Island Women and Infants Hospital of Rhode Island	All newborn care is a single cost center	Each hospital negotiates with Blue Cross and medicaid and establishes charges to be uniformly applied to all patients	No information	Contract with individual hospitals to reimburse services based on prospective Costs	Contract with individual hospitals to reimburse services based on prospective costs. Medicare reimburses hospital based on actual costs	Pay direct for care

SOURCE S L Kaufman and D S Shepard, "Reimbursement of Neonatal Intensive Care" A Descriptive Overview," in *A Review of Planning Methods for Neonatal Care Units. vol. II,* HRA contract' No 231-770108 study prepared by the Boston University Center for Health Planning for the Health Resources Administration, Hyattsville. Md 1979

Table 16.—Who Pays the Bill? (accounts paid in full)

Third-part y payer	Number of accounts	Total hospital charges	Amount paid by third-party	Amount paid by family	Amount written off by hospital
Blue Cross-.	54 (360/.)	$491,119	$457,757	$24,994	$8,368
Commercial insurance	53 (36°/0)	490,982	439,355	27,703	23,924
Medicaid.	23 (150/o)	256,750	159,726	1,000	96,024
Kaiser	6 (4°/0)	148,748	148,748	0	0
Other third-party payer[a]	11 (70/o)	109,692	80,135	1,002	28,555
No coverage.	3 (2°/0)	10,210	0	3,502	6,708

[a]Includes Handicapped Children Program

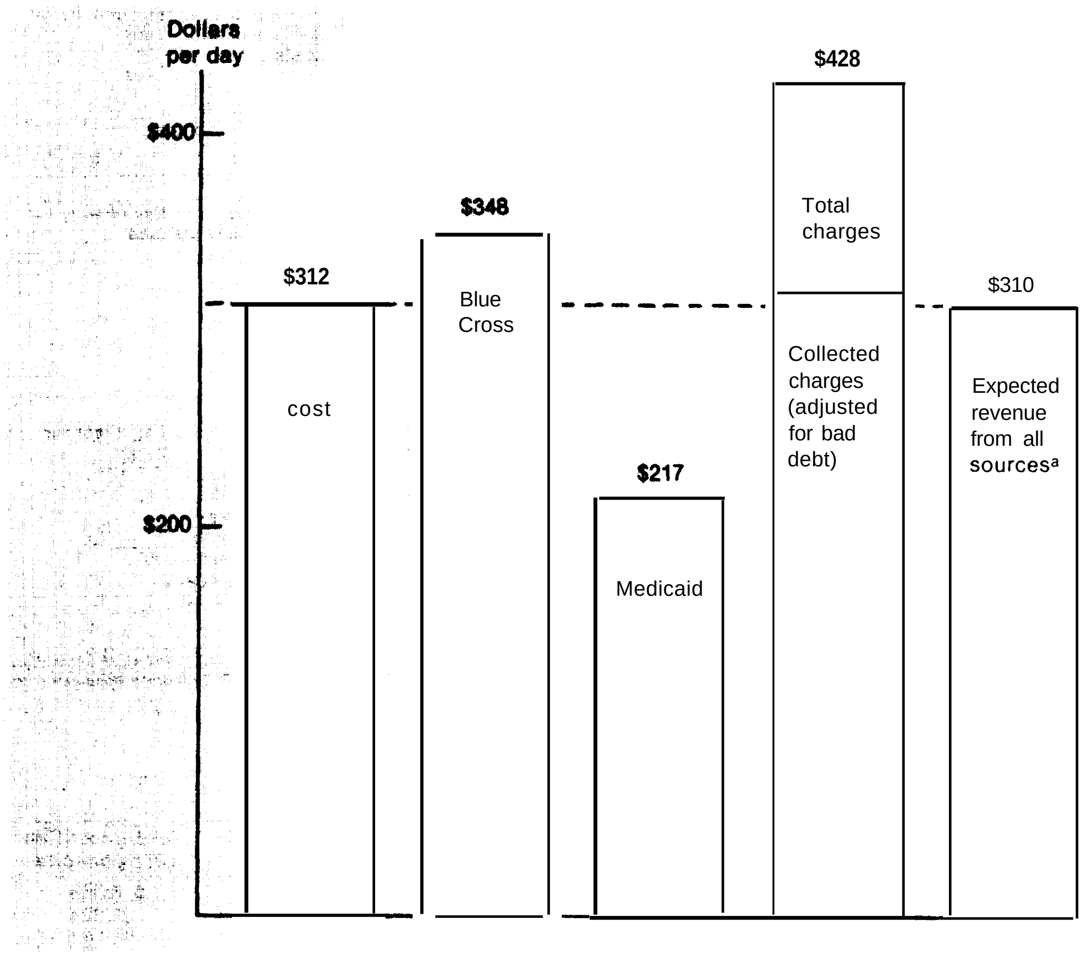
SOURCE :J. T. McCarthy, et al., Who Pays the Bill for Neonatal Intensive Care?" J. *Pediatrics 95 :757, 1979*

hospital charges both exceeded the average cost per patient day overall, while medicaid reimbursement was considerably less than costs. Using a weighted average of all three reimbursement methods based on the hospital's patient mix, the authors calculated on a preliminary basis the expected revenue from all sources and found it to be $2.00 per day below costs.

The same authors also demonstrated how length of stay produces cross-subsidies. Blue Cross and charge-payer reimbursements were highest during the first week, and decreased significantly through the fourth week. Medicaid per diem, on the other hand, steadily reimbursed below costs through the eighth week of hospitalization. Short or long stays determine whether total reimbursement calculated on a fixed per diem basis will be above or below costs, dependin g on the payer.

Kaufman and Shepard (66) recommended two options for improving the present reimbursement system to create incentives for cost

Figure 1.—Comparison of Average Daily Cost and Reimbursement From Various Sources for 10 Infants (birthweight 750 to 999 g) in Neonatal **Intensive Care**



[a]Weighted average of the three reimbursement sources based on hospital's patient mix Blue Cross, 41 7 percent, medicaid, 20 8 Percent, charge payers, 375 Percent

SOURCE S L Kaufman and D S Shepard, "Cost by Day of Neonatal Intensive Care, " speech delivered at the 108th Annual Meeting of the American Public Health Association, Detroit, Mich Oct 19-23, 1980 savings and for quality. The first would be to reimburse at a flat rate for each case and eliminate per diem payments completely. A New Jersey experiment with such a payment system is about to begin, but this will have only limited application to neonatal intensive care because very broad diagnostic groupings are used (e.g., with and without distress). A second reimbursement option is a per diem rate that declines over the course of an infant's hospital stay. This proposed option might create incentives for return transports to community hospitals for growth and recovery (66). Whatever alternatives are selected, it is evident from experience that the present approach, a uniform per diem rate, provides incentives for inequitable cross-subsidization in the reimbursement of neonatal intensive care.

EFFECTIVENESS OF NEONATAL INTENSIVE CARE

Neonatal intensive care brings together complex medical technologies and highly specialized personnel to improve the survival of premature and ill newborns. The first indicator of the effectiveness of this care must be whether such infants do in fact have a better chance of survival with intensive care than without it. Randomized clinical trials are very limited, but more extensive mortality reports are available. Taken together, the data strongly suggest that neonatal intensive care is effective in improving survival. All reports from this country show remarkable declines in mortality during the years in which neonatal intensive care proliferated.

Survival statistics alone, however, leave unanswered the central question of whether the recent improvements in infant survival actually are due to intensive medical care of the newborn, or whether they are the result of other factors such as lower prematurity rates or improved maternal health and nutrition. This complex question is dealt with in some detail in the discussion presented below, but is not easily resolved. On balance, the available evidence and some recently applied analytic methods allow us to conclude that neonatal intensive care has played a major role in improving the chances of survival of many newborns, particularly those of very low birthweight, even though it is impossible to quantify precisely how much of the improvement is due to medical care.

A second and equally important question left unanswered by survival figures is whether the increased number of infants being saved will be able to lead normal lives, or whether they will suffer from serious handicaps such as cerebral palsy and mental retardation. This question is perhaps even more perplexing than the issue of survival, for two reasons. First, the data on morbidity of survivors of intensive newborn care are limited and do not allow definitive conclusions. It appears reasonable, however, to conclude that the incidence of serious problems has not increased and is probably decreasing. Second, the absolute number of severely handicapped individuals can increase at the same time the incidence of serious problems is decreasing. This unpredicted and seemingly contradictory situation would result if mortality rates fell faster than the incidence of serious complications. Our analysis shows that this may be happening, especially in the subgroup of the smallest infants, those weighing 1,000 g or less. Thus, while the number of normal survivors has increased eightfold to twentyfold since 1960, the small but worrisome number of severely handicapped individuals may have doubled. Morbidity studies are made even more difficult by the fact that some handicaps are not discovered until the children are of school age.

As discussed in the next part of this case study, these results illustrate the dilemma of trying to determine whether intensive care of the newborn is cost effective. Every year, several thousand babies who would have died are now surviving to lead normal lives. Part of the price for this success, however, is a persistently significant number of abnormal survivors.

Mortality

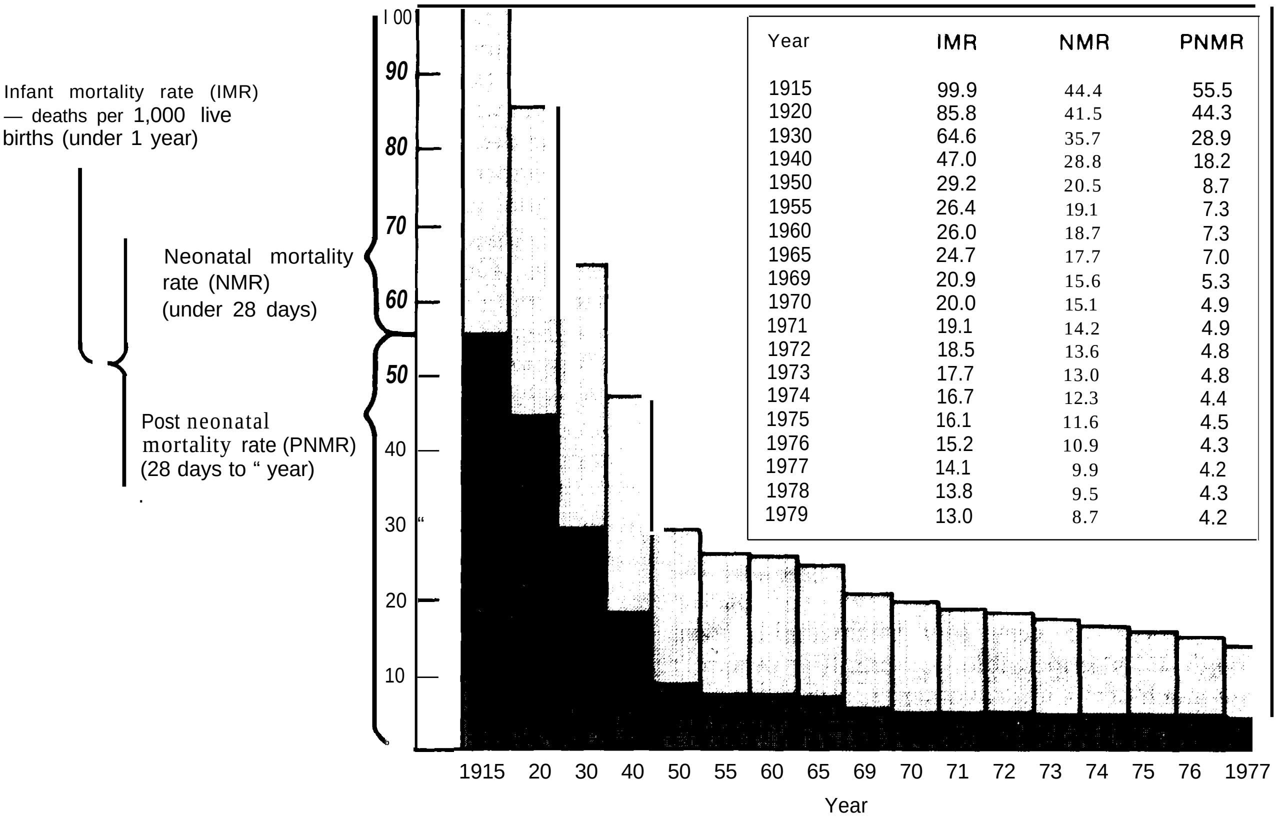
Remarkable improvements in infant mortality have occurred in this country since 1915, as demonstrated in figure 2. Infant mortality includes all deaths during the first year of life. Deaths in the neonatal period (the first 28 days) are referred to as "neonatal mortality, " and the rate of neonatal mortality should be influenced by improvements due to the intensive care of newborns.

Most of the decline in infant mortality had taken place by 1950 and cannot be attributed to neonatal intensive care. Between 1950 and 1965, the infant mortality rate continued to decline, but at a slower rate. During that period, nearly 60 percent of the decline in infant mortality was in deaths during the neonatal period. The end of that era coincides with the introduction of NICUs and of perinatology as a medical subspecialty.

Since 1965, infant mortality has fallen by over 40 percent, declining at 3.6 percent annually, as compared with the 1 percent per year fall during the 1950 to 1965 period. Nearly all (90 percent) of the decline in infant mortality since **1970** has occurred in the neonatal period.

Because the most recent improvements in the neonatal mortality rate were concurrent with the proliferation of intensive care of the newborn, a number of studies have been undertaken to see whether the changes are, in fact, due to modern medical care. The evidence collected falls into four categories: 1) clinical trials, **2)** epidemiological surveys, 3) reports from indi-

Figure 2.— Infant, Neonatal, and Postneonatal Mortality Rates: United States, 1915-77



Year	IMR	NMR	PNMR
1915	99.9	44.4	55.5
1920	85.8	41.5	44.3
1930	64.6	35.7	28.9
1940	47.0	28.8	18.2
1950	29.2	20.5	8.7
1955	26.4	19.1	7.3
1960	26.0	18.7	7.3
1965	24.7	17.7	7.0
1969	20.9	15.6	5.3
1970	20.0	15.1	4.9
1971	19.1	14.2	4.9
1972	18.5	13.6	4.8
1973	17.7	13.0	4.8
1974	16.7	12.3	4.4
1975	16.1	11.6	4.5
1976	15.2	10.9	4.3
1977	14.1	9.9	4.2
1978	13.8	9.5	4.3
1979	13.0	8.7	4.2

SOURCE National Center for Health Statistics, *Vital Statistics of the United States*, selected years vidual intensive care units, and 4) analyses of birthweight-specific mortality rates.

Clinical Trials

There has been only one randomized controlled clinical trial of intensive care versus routine care of neonates (68). That study, done in Australia in 1966-70, showed improved survival as intensive care experience developed, particularly for infants with respiratory distress. At least one leading neonatologist attributes the paucity of such studies to the notion that "controlled clinical trials of perinatal intensive care and regionalization have been neither feasible nor morally acceptable" (127). There also have been clinical trials of some individual intensive care therapeutic techniques. A recent clinical trial demonstrated improved mortality and shorter periods of hospitalization for infants who were transported under the care of a specialized neonatal team compared with those transported by the local ambulance authority (26).

The recent debate over the efficacy of continuous positive airway pressure (CPAP) devices in the treatment of RDS illustrates the status of most of the clinical evidence, however. This therapy has been hailed as a breakthrough responsible for marked improvement in the survival of infants with RDS. However, the first controlled clinical trial was not conducted until several years after widespread adoption of CPAP, and that study was not able to document statistically significant improvement in mortality (16). Publication of that report in the pediatric literature was accompanied by a long editorial reiterating the abundant evidence for the effectiveness of CPAP and detailing possible deficiencies of the controlled study, while expressing general support for clinical trials (133). In short, many newborn therapies are unproven and even controversial. Thus, no overall conclusions can be reached from the clinical literature alone.

Epidemiological Surveys

Epidemiological evidence suggests that medical care has helped lower mortality rates, but for the reasons discussed below, the evidence is not convincing. The Canadian experience showed a .50-percent decline in neonatal mortality in Toronto in the decade following organization of special neonatal care facilities (121). An analysis of data for the United States between 1955 and 1973 demonstrated that, in general, mortality rates fell with increasing urbanization (41), but urban areas were not stratified in terms of levels of intensive care available for newborns. Thus, no conclusions could be drawn about the relationship between urban medical care and mortality.

A major review article summarized reports from various parts of the United States, all of which showed declines of 23 to 42 percent after the development of regional intensive care facilities (125). Our own analysis confirms that these declines were generally greater than were experienced for the United States as a whole during the same years. Although these data are suggestive that development of regional intensive care centers improved the outlook for infants in surrounding areas, the studies do not consider whether prematurity rates fell during the same period. Since declines in prematurity can markedly reduce neonatal mortality rates independent of changes in medical care, this omission greatly reduces the conclusions that can be drawn from these reports.

We conducted an analysis of other crude epidemiological evidence and failed to find any support for the hypothesis that increasing access to neonatal intensive care has had a large-scale effect on neonatal mortality rates. Comparing the reduction in neonatal mortality rates for each State between 1971 and 1977 with the number of tertiary care neonatal intensive care beds per 1,000 live births that were reported at the end of that period revealed no consistent relationship between the two variables. Our analysis is inconclusive since the development of NICUs in many areas might have been disproportionate to actual need. Moreover, the data on the number of beds are not fully reliable.

Sequential Reports From Individual Intensive Care Nurseries

Most of the literature on the effectiveness of neonatal intensive care consists of reports detailing the experience of individual nurseries. Twelve of these reports were recently reviewed; all demonstrated reductions in inborn neonatal mortality, ranging from 17 to 56 percent (125).

The impact that changes in prematurity rates can have on mortality experience, however, limits the value of these reports. If the distribution of births among birthweight groups changes from year to year, so that very small infants represent a lower proportion of total births, mortality experience will fall substantially. The proportion of infants in the very low birthweight category (1,500 g or less) has the greatest impact on mortality rates (69). Because very low birthweight infants have a very high mortality rate, any decrease in the proportion of such infants will have a significant impact on neonatal mortality.

The experience of the Bronx Municipal Hospital Center illustrates this phenomenon clearly (71). In that hospital, between 1966-71 and 1972-73, the in-hospital neonatal mortality rate declined from 16.9 per 1,000 live births to 11.2 per 1,000 live births. Over 75 percent of the decline could be attributed to changes in the proportion of very low birthweight infants (1,500 g or less). This institution's experience demonstrates that even if no improvements due to medical care after birth are taking place, there can be impressive declines in neonatal mortality if a smaller proportion of high-risk infants is being born.

Clearly, reports on overall mortality must specify birthweight distribution if they are to help determine the effectiveness of newborn medical care. If mortality rates within specific birthweight groups improve over time, this would be a strong indication that neonatal intensive care is having a beneficial impact. For example, if infants of 1,500 g birthweight or less have a better chance of surviving after introduction of neonatal units, such a change must be due to "either improved neonatal medical care or to improved health status of the infants at birth, or both" (71).

A large number of nurseries have reported mortality rates by birthweight before and after the introduction of an intensive care facility (2,57,99,107,110,125,126,127). The results for every nursery but one (61) show impressive declines in birthweight-specific mortality over time. Attributing most of these improvements to newborn medical care, Thompson and Reynolds stated: "NICUs have more than justified their reason for existence, reducing by approximately one-half the risk of neonatal death" (125).

Even birthweight-specific reports from individual nurseries are of limited usefulness, however, because of their small population samples. Often, only 20 to 30 infants in the very low birthweight groups are born during the study period, making it difficult to determine whether improvements over time are statistically significant. For this analysis, we grouped all available reports of mortality rates for inborn infants into 5-year periods beginning in 1961. These pooled data demonstrate significant declines over time for very low birthweight infants (see tables 17 and 18 and figure 3). Mortality for infants with birthweights of 1,001 to 1,500 g has fallen from more than 50 percent to less than 20 percent, while that for the extremely small newborns (1,000 g or less) has fallen from nearly 94 percent to approximately 50 percent.

Birthweight-Specific Mortality Rate Analyses

It is not possible to compare the experience in individual nurseries to the survival rates of infants of similar birthweights who were not cared for in intensive newborn units. As pointed out above, it is difficult to identify with confidence the levels of care available at different hospitals. Moreover, not all States link birth certificates with death certificates, so it is impossible to know on a routine basis the birthweight of individual infants who die. Data for all births in California (where birth and death certificate data are compiled) have been collected, however, and show major improvements in neonatal mortality between 1960 and the present (128),

Table 17.—Inborn Neonatal Mortality Rates, Birthweight 1,001 to 1,500 Grams

Hospital[a]	Years reported if other than headings	1961-65 Deaths/births	1961-65 Rate[b]	1966-70 Deaths/births	1966-70 Rate[b]	1971-75 Deaths/births	1971-75 Rate[b]	1976- Deaths/births	1976- Rate[b]
UCSF (99).		26/55	473	23/63	365	15/80	188	9/68	132
Cambridge Maternity (107)	1976-78							23/96	240
Royal Victoria (127).				25189	281	14/90	156		
Harvard (135), ...	1975-78							37/213	174
University of Washington, Seattle (60).	1978							14/75	187
Medical Center, Columbus, Ga. (126).	1959-68	116/219	530						
	1969-70			14/44	318				
	1971-72					14/41	341		
Bronx Municipal (71).	1966-71			69/193	358				
	1972-73					11/42	262		
Simpson Memorial Edinburgh (37)	1966-70			71/04	461				
E. Hospital, Goteberg, Sweden (1 10)	1969-70			10/24	417				
Total.		142/274	518	212/567	374[c]	54/253	213[c]	831452	184[d]

aNumbers in parentheses refer to references in the list that appears at the end of this case study
bRate = deaths/1,000 live births
cSignificantly different from preceding 5-year rate (p<.01)
dNot significantly different from 213 (1971-75).

Table 18.—Inborn Neonatal Mortality Rates, Birthweight <= 1,000 Grams

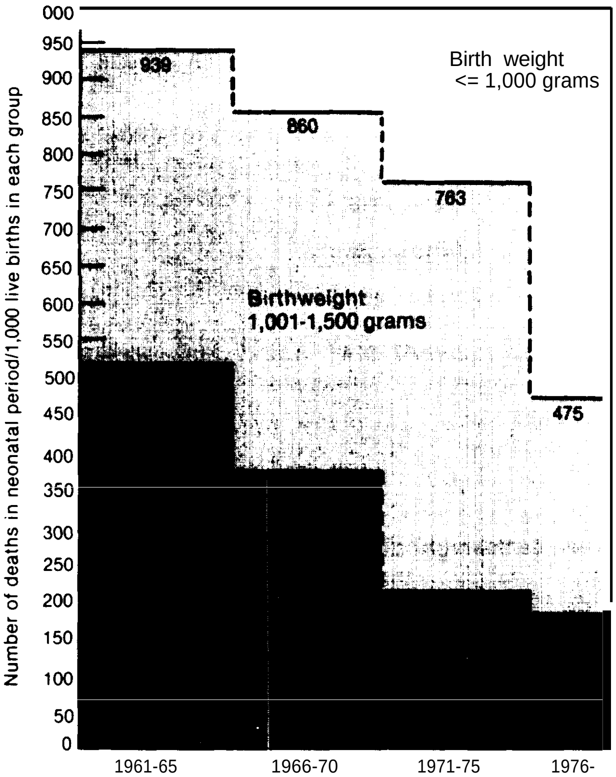
Hospital[a]	Years reported if other than headings	1961-65 Deaths/births	1961-65 Rate[b]	1966-70 Deaths/births	1966-70 Rate[b]	1971-75 Deaths/births	1971-75 Rate[b]	1976- Deaths/births	1976- Rate[b]
UCSF (99).		28/29	966	26/34	765	22/33	667	15/30	500
Children's, San Francisco (57)	1972-75					30/35	857		
	1976-77							8124	333
Cambridge Maternity Hospital (107).	1976-78							9/25	360
Royal Victoria (127).				65/73	890	58175	773		
University of Washington, Seattle (60).	1978							25/41	610
Medical Center, Columbus, Ga. (126)	1959-68	157/168	935						
	1969-70			27134	794				
	1971-72					26135	743		
Bronx Municipal (71).	1966-71			119/138	862				
	1972-73					18/25	720		
University of Illinois (17)	1974-76					29/38	763		
Simpson Memorial Edinburgh (37)				84/92	913				
University College Hospital, London (1 19).				29/36	805	26/33	788		
E. Hospital, Goteberg, Sweden (1 10)	1969-70			417	571				
Total.		185/197	939	381/443	860[c]	209/274	763[c]	57/120	475[c]

aNumbers in parentheses refer to references in the list that appears at the end of this case study
bRate = deaths/1,000 live births
cSignificantly different from preceding 5-year rate (P<.01)

Analysis of these data by Ronald L. Williams of the University of California, Santa Barbara, supports the hypothesis that medical care was a major factor in the lowering of mortality rates (129,130). For infants in all hospitals in California, Williams found that once the risks faced at each hospital are taken into account, Level III hospitals have far better survival rates than Level I hospitals, and hospitals with large delivery services and high specialist-to-generalist ratios have the best performance.

The fact that mortality rates within birthweight groups have declined over time strongly supports the conclusion that neonatal intensive care has helped improve survival. One could question, though, whether there were also underlying changes in the health status of infants within each weight group that improved

Figure 3.—Pooled Neonatal Mortality Data, 1961.76



SOURCE. See tables 17 and 18;

neonatal mortality independent of intensive newborn medical care. Such changes could be the result of medical or nonmedical factors. Medical factors, such as intensive intrapartum obstetric care or steroid therapy during premature labor to prevent HMD, could produce infants more likely to survive in the extremely fragile low birthweight groups. Obstetric care during pregnancy prior to labor would not be expected to affect birthweight-specific mortality rates, but to reduce the chances of low birthweight.

Nonmedical factors such as improved maternal nutrition and socioeconomic status also have their primary beneficial effect through higher birthweights (86,123). However, it is possible to speculate that better maternal nutrition and general health results in subtle biochemical or other changes that further increase the chance of survival for infants in each weight group. Unfortunately, none of these hypotheses can be established or rejected with confidence from the available data.

As noted above, Williams has analyzed changes in mortality rates among newborns in California over the past two decades (128,130). Between 1960 and 1977, the neonatal mortality rate in California fell by 57 percent. During the same period, prematurity rates also declined. It was necessary, therefore, to partition the improvement in neonatal mortality into the part due to changes in birthweight distribution and the part due to other factors, including medical care. In contrast with the result noted above for Bronx Municipal Hospital Center ***(7l),*** Williams analysis showed nearly 85 percent of the remarkable decline in neonatal mortality in California was due to birthweight-specific declines. That is, the reduction in prematurity accounted for only about 15 percent of the decline in neonatal mortality, while medical care and/or better health status of individual infants accounted for the remainder. More than half of the overall decline could be attributed to improvements in the mortality rates of low birthweight infants. Blacks experienced lower mortality rates than whites, even though their birthweight distribution actually became less favorable over the 1960 to 1977 period.

Kleinman and others at the National Center for Health Statistics analyzed data from six States and reached similar conclusions (69). They found that weight-specific changes accounted for nearly 80 percent of the decline in early neonatal mortality rates. More than half of the overall decline was due to improvements in mortality among the low birthweight groups. These investigators estimated that for the nation as a whole, about 83 percent of the decline in early neonatal mortality for whites and 97 percent of the decline for nonwhites could be attributed to factors other than changes in birthweight.

The same investigators discussed factors that could be causing the decline in birthweight-specific mortality rates. They rejected a suggestion that lower death rates were merely an artifact due to improved registration. They also concluded it was unlikely that any major shift in distinctions between live births and fetal deaths (stillbirths) had taken place, since fetal deaths were also declining, Finally, they attempted to deal with the question of whether infants within given birthweight groups might have different risk characteristics over time. Kleinman and his colleagues found that comparing gestational age distributions made no difference for the calculation, and they concluded ***(69):***

> The most likely explanation for at least part of the recent decline in mortality levels among low birthweight infants is the development of the medical technology for the successful management of premature infants and the consequent proliferation of this technology. While there are many components of the technology which have not been critically evaluated, there are indications of effectiveness.

Lee, et al. (72) examined the effect of birthweight changes on the improvements in neonatal mortality in the United States between 1950 and 1975. They determined that no improvement had taken place in the weight distribution or, with the exception of perinatal medical care, other factors known to affect survival. Their conclusion, similar to that of Williams (129) and Kleinman, et. al. (69), was that (72):

> The most plausible explanation . . . is the steady improvement in perinatal medical care which has made for greater infant survival at a given birthweight.

Most recently, these same investigators used birthweight-specific analysis to examine variations in the neonatal mortality among the 50 States and the District of Columbia, and among 13 industrialized nations. They confirmed the role of the very low birthweight rate in predicting neonatal mortality—that rate accounted for about three-quarters of the variance among the populations studied (73). They suggest that variance of neonatal mortality after holding constant the very low birthweight rate might be a useful preliminary indicator of the quality of newborn care.

Birthweight-specific analyses are helpful in answering part of the question regarding the role of medical care in bringing about improvements in infant mortality, but they do not settle all the issues. By estimating that about 15 percent of the decline in overall mortality rates is simply the result of changes in birthweight distribution, these analyses define the maximum impact on survival that could be attributed to medical care of the newborn. However, this is not to say that all of the remaining 85 percent is necessarily due to neonatal medical care. As noted above, there might be medical or other factors producing infants more likely to survive.

Some limited evidence that mortality rates can improve even in the absence of high grade neonatal medical care precludes our assuming that medical care is responsible for all the improvement in birthweight-specific rates. One recent and unfortunately rather sketchy report describes a British hospital's experience in managing ill and premature babies with little or no intensive care (59). No respirators, phototherapy, CPAP device, or extensive mask and glove isolation were used in the nursery. Some modern techniques, including initial resuscitation, catheterization of umbilical vessels, exchange transfusions, and incubators were applied. The absolute levels of mortality achieved in each weight category would clearly be unacceptable at a major nursery in the United States. However, there **was** very significant annual improvement within birthweight groups. On the basis of this limited report, one is not able to conclude whether this nursery is, in fact, able to improve mortality without changing neonatal care and without delivering the most advanced methods. No other evidence is available to help determine the precise contribution of neonatal *care* in improving birthweight-specific mortality rates.

In sum, while it may be impossible to determine the precise role that neonatal intensive care has played in lowering mortality rates among low birthweight infants, the evidence supports the conclusion that neonatal care has been a significant factor. The degree, if any, to which infants are somehow improving in their inherent survivability from year to **year** and the role of intensive intrapartum obstetric care could be tested only through controlled clinicaI trials, and such trials are unlikely to be conducted,

Morbidity

When it first appeared that neonatal intensive care would save ill and premature infants who otherwise would have died, many concerns were voiced that the net result would be a large number of highly defective survivors. Some early studies, particularly those by Lubchenco (74,75) and Drillien (38), seemed to corroborate this fear. They reported that many of the survivors of their premature nurseries in the 1940's and 1950's were afflicted with serious problems. These included necrologic defects, particularly cerebral palsy, mental retardation of varying degrees, blindness and other visual defects, growth failure, hearing loss, and chronic respiratory disease. All of these problems are still found to a significant degree in the survivors of present day intensive care nurseries. The incidence of problems appears to have fallen in recent years, but the available data for the most part permit only tentative estimates, not definitive conclusions.

Incidence of Serious Handicaps

Many articles have claimed that the incidence of severely handicapping conditions has declined remarkably in recent years (see tables 19 and 20). However, these reports all suffer from serious limitations. The most critical shortcoming is that the studies are based on survivors of individual nurseries. Morbidity data are not collected on a routine basis in the United States. Thus, the incidence of problems and trends over time in the general population cannot be determined. Second, the reports cover a variety of different aspects of morbidity, some emphasizing neurological diseases and others focusing on problems specific to the cardiovascular system or respiratory tract. It is often impossible to determine, for example, whether survivors with neurological disease also had chronic respiratory disease, or whether "normal" survivors in a study emphasizing neurological disease were afflicted with cardiovascular problems. In addition, the reports have used different measures of

Table 19.—"Serious Handicaps," Birthweight <= 1,500 Grams[a]

Year bomb	Number of survivors	Serious retardation (IQ-DQ <70)	Major neurological defects	Serious hearing defect	Retrolental fibroplasia[c] Present	Retrolental fibroplasia[c] Blind	Survivors with 1 or more serious handicaps Percent	Survivors with 1 or more serious handicaps Number
1968-74 (18)	205	10	7	—	—	—	8%	17
1971-72 (21)	16	0	3	—	—	—	19	3
1948-56 (38)	49	12	7	2		6	43	21
1966-71 (37)	88	9	7				—e	—e
1970-72 (44)	232	—	44	—	—	—	19	44
1964-69 (52)	42	6	8	—	—	—	—e	—e
1973-74 (58)	42		0				2	1
1947-53 (74,75)	133	([d])	32	14	33	9	31[f]	28[f]
1969-70 (1 10)	17		0				—e	—e
1966-69 (105)	68	3	3	—	—	—	7.4	5
1965-70 (124)	176	25	20	.	—	—	20	35
1940-57 (35)	100	5	5	1	11	—	18	18
	60	32	—	—	16		67	40
1952-56 (132)	65	—	17				26	—e
1951-53 (81)	240	—	22				9.2	—e
pre-1960 (96)	44	—	10				23	—e
1961-65 (59)	49	—	—	—	—	—	14.3	7
1966-75 (61)	94	—	—	—	—	—	12.8	12

— = not specified.
aUnless otherwise noted
bNumbers in parentheses refer to references in the list that appears at the end of this case study
cScarring of the internal eye.
dIncludes IQ 80 as major handlcap.
eCould not be calculated from repel ted data
fof 91 who were examined

Serious handicap rates among survivors
Pre-1960: 24% (156/649)
Post-1965: 13.6%(1 16/850)

Table 20.—"Serious Handicaps," Birthweight <= 1,000 Grams[a]

Year bomb	Number of survivors	Serious retardation (IQ-DQ <70)	Major neurological defects	Retrolental fibroplasia[c] Present	Retrolental fibroplasia[c] Blind	Survivors with 1 or more serious handicaps Percent	Survivors with 1 or more serious handicaps Number
1965-70 (2) . . .	20	2	1	3	3	20"/0	4
1974-76 (17) .	16	—	3	—	—	19	3
1968-74 (18)	27	—	—	—	—	7	2
1940-52 (36)	42	5	2	1	—	14.3	6
1968-70 (40)	14	0	2	—	—	14.3	2
1948-54 (38) .	7	4	0	1	1	57	4
1968-72 (51)	27	0	4	2	—	18.5	5
1974 (95).	43	7	6	7	2	21	9
1969-70 (110)	3	0	0	—	—	0	0
1966-74 (1 18)	27	1	1	—	1	7	2
1965-70 (124)	40	6	6	—	—	20	8
1947-50 (75) . . .	7	—	—	—	—	100	7
1960-66 (44) . .	5	—	—	—	—	40	2
1961-68 (47)	12	—	—	—	—	17	2

— = not specified
aUnless otherwise noted
bNumbers in parentheses refer to references in the list that appears at the end of this case study
cScarring of the internal eye

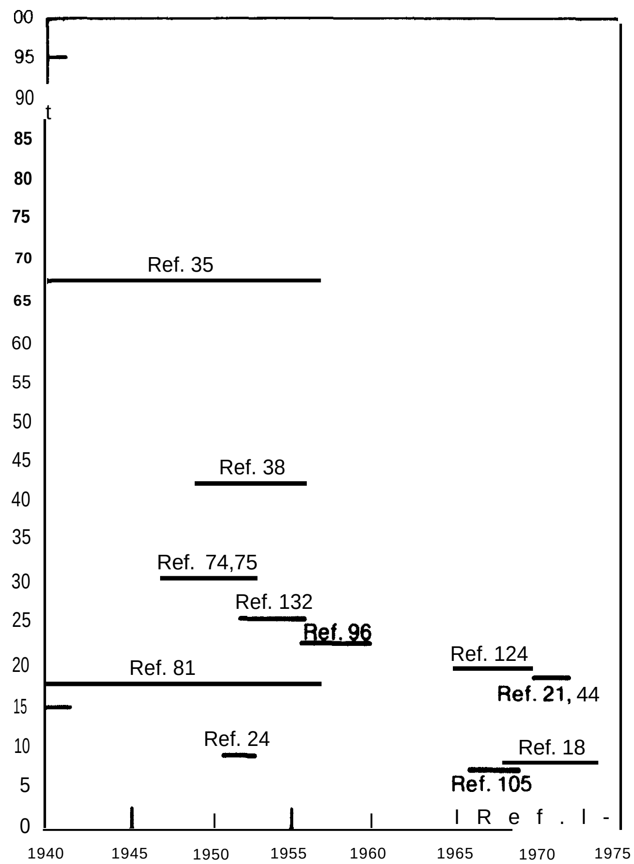
Serious handicap rates
among survivors
Pre-1965: 29% (21/73)
Post-1965: 16 % (35/217)

the various defects, and have studied survivors at varying ages, thus making the findings difficult to compare.

In general, the incidence of serious handicap is inversely proportional to birthweight. The most serious and frequent problems are reported in infants with very low birthweight, that is, less than 1,500 g. Tables 19 and 20 summarize a large number of reports on the incidence of serious handicap in very low birthweight infants. Throughout this analysis, "serious handicaps" are defined as the following: severe mental retardation (IQ or developmental quotient below 70); cerebral palsy of significant degree (spastic diplegia, paraplegia, tetraplegia, hemiplegia); major seizure disorders; and retrolental fibroplasia (scarring of the internal eye) with blindness or significant residual impairment of vision.

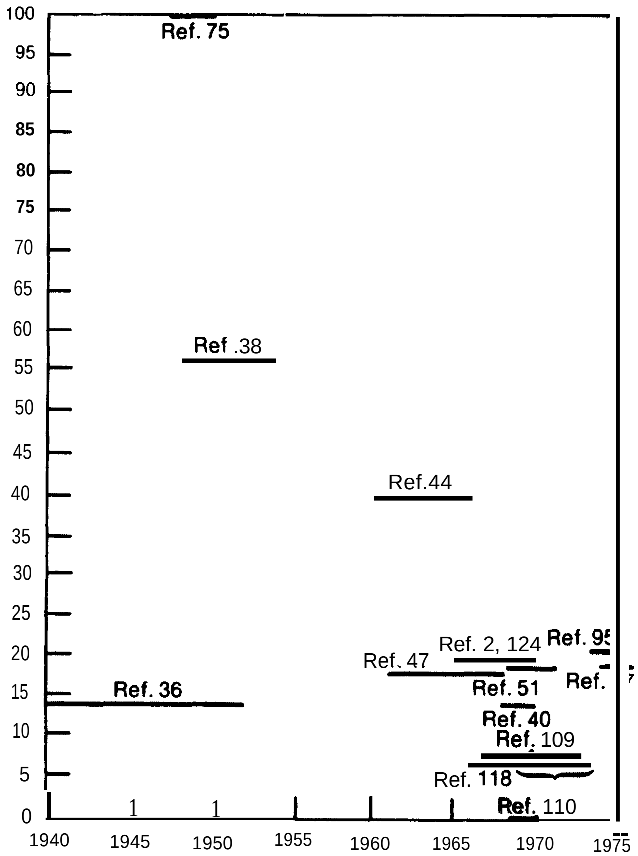
Figures 4 and 5 illustrate the findings of these studies over time. It appears there has been some narrowing of the range of reported handicaps, as well as a reduction in the incidence of severely affected infants, in the most recent years. For infants weighing 1,500 g or less, there appears to have been approximately a 40-percent decline; before 1960, about one-fourth suffered severe neurological and other handicaps, while recent reports average under 14 percent.

Figure 4.—"Serious Handicaps," Birthweight <1,500 Grams



SOURCE See table 19

Figure 5.—"Serious Handicaps," Birthweight <1,000 Grams



SOURCE See table 20

The results for infants weighing 1,000 g or less are comparable. They suggest a decline from about 30 percent of those affected to some 16 percent.

Several serious problems limit the conclusions which can be drawn from these reports. First, it is not clear how the populations being studied may have been biased toward either favorable or unfavorable outcomes. The condition of infants entering a given nursery for immediate neonatal care and the proportion of surviving infants returning for followup studies are dependent on a wide variety of uncontrolled factors. For example, one author published a followup study which tracked down data on most of the survivors who had not returned to be studied and found that many were institutionalized or seriously afflicted (35). Second, the total number of reports and infants studied is small. Infants weighing 1,500 g or less totaled about 1,400 patients, and the entire literature on infants weighing 1,000 g or less includes only about 300 individuals over nearly 40 years. Finally, the reports do not always use standardized criteria or ages for the followup analyses.

These data from the literature cannot be relied on with full confidence for the reasons listed above. They do, however, correlate reasonably well with, and thus are supported by, the results now appearing from the first large population-based study of morbidity by birthweights. Sam Shapiro and others at Johns Hopkins University have studied the low birthweight population of eight regions in the United States (115). In their first report, they noted that for infants with birthweights of 1,500 g or less and born in the first half of 1976, the incidence of severe impairment was 14.3 percent, very nearly the same as the figure we calculated from the literature. These data constitute a preliminary baseline for an evaluation of the impact of further perinatal regionalization, and as such, they are not necessarily representative of the outcomes expected for the maximum level of intensive care. Nevertheless, the findings are relevant for this analysis, since newborn intensive care centers were in operation in all regions studied, and infants in the very low birthweight groups are very likely to have been cared for within the existing centers.

Neurological and Intellectual Defects

Although the numbers for each reported complication become increasingly small as one separates out each adverse outcome, major neurological defects such as cerebral palsy, seizure disorders, and hydrocephalus are among the most commonly noted complications. The reports that allow one to identify infants with neurological defects suggest a reduction in the incidence of such problems, from an average of 16 to 18 percent prior to 1965, down to approximately 10 to 11 percent among infants weighing 1,500 g or less in recent years (see table 19). The results for infants weighing 1,000 g or less suggest an apparent increase over time, but the absolute number of infants reported on in this birthweight category was too low to allow any conclusions (see table 20).

Infants may suffer severe mental retardation whether or not serious neurological damage is also present. In the studies before 1960, about one-fourth of all infants weighing 1,500 g or less were seriously retarded. In the reports since 1965, there has been an apparent decline of severely retarded infants to less than 10 percent (see table 19). Parallel figures have been reported for infants weighing 1,000 g or less, but, again, the number of infants reported in this birthweight category prior to 1960 is quite small (see table 20).

In sum, it appears that the incidence of severe neurological damage has declined, and the current incidence is on the order of 10 percent of very low birthweight survivors. Similarly, the incidence of severe mental retardation has probably declined, and is less than 10 percent.

In addition to concerns that neonatal intensive care would produce severely impaired infants, there have also been widespread fears that the relatively normal survivors would have a high incidence of moderate impairment. This category would include infants with IQs or developmental quotients between 70 and 80, infants who have "soft" necrologic signs, and infants who develop behavior, learning, and language disorders. These infants comprise a group with moderate or minor intellectual or neurologic damage. It is not possible to estimate changes in this group over time because of the limited data. Present data indicate that on the order of 10 to 12 percent of infants weighing under 1,500 g will suffer intellectual or neurologic problems that do not constitute major handicaps.

Data on the incidence of learning, language, and behavior disorders, along with all information on other minor handicaps, are in many ways less reliable than those reported for severe handicaps. That is because the definition of severe handicap is more precise and because the recognition of problems such as hydrocephalus or cerebral palsy is much more pressing and more likely to cause parents to seek medical attention than is the recognition of learning and language disorders or mild neurological impairment. Moreover, great caution is needed in interpreting data on minor problems because there are no reliable standards for the incidence of behavior, language, and mild necrologic problems in the general population of children.

General Health of Low Birthweight Survivors

The Johns Hopkins study referred to above (115, 136) is an important new source of information which allows one to compare the overall problems of low birthweight infants with those suffered by full-term infants. Among survivors of birthweight 1,500 g or less, nearly 40 percent were hospitalized at least once during the first year of life, compared to just over 8 percent of infants weighing 2,500 g or more. Even when infants with severe impairments and moderate or minor congenital anomalies are excluded, still more than one-fourth of the otherwise normal, very low birthweight infants were hospitalized, compared to only about 7 percent of all infants. When all serious illnesses were taken into account, less than 40 percent of the infants weighing 1,500 g or less were free from morbidity during their first year of life, compared to over 70 percent of all infants free. It is clear that extremely low birth weight survivors carry a very high burden of illness.

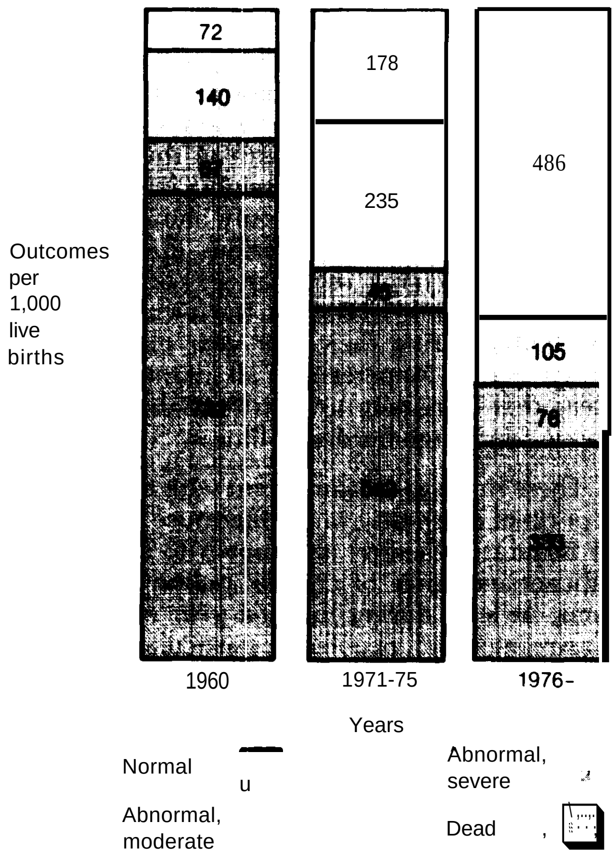
These findings are consistent with the isolated reports of morbidity in the literature. Survivors of respirator therapy are known to have a significant incidence of chronic pulmonary problems, at least during the first year of life (45). Gastrointestinal problems, particularly failure to thrive, are quite common among extremely low birthweight infants. Other indicators of morbidity which have been documented include visual impairment, particularly severe myopia, and minor hearing defects. Some of these problems will disappear over time. For example, most recent studies have demonstrated that all but a very small proportion of low birthweight infants do attain relatively normal stature by early childhood (18,25).

Conclusion

Over the past 10 to 15 years, since neonatal intensive care methods have been applied, there has been a dramatic improvement in survival of low birthweight newborns, and most of the survivors are normal (see figures 6 and 7). While it is impossible to say precisely what proportion of this improved outlook is due to each of the possible factors mentioned above, the evidence strongly suggests that medical care of the newborn deserves much of the credit.

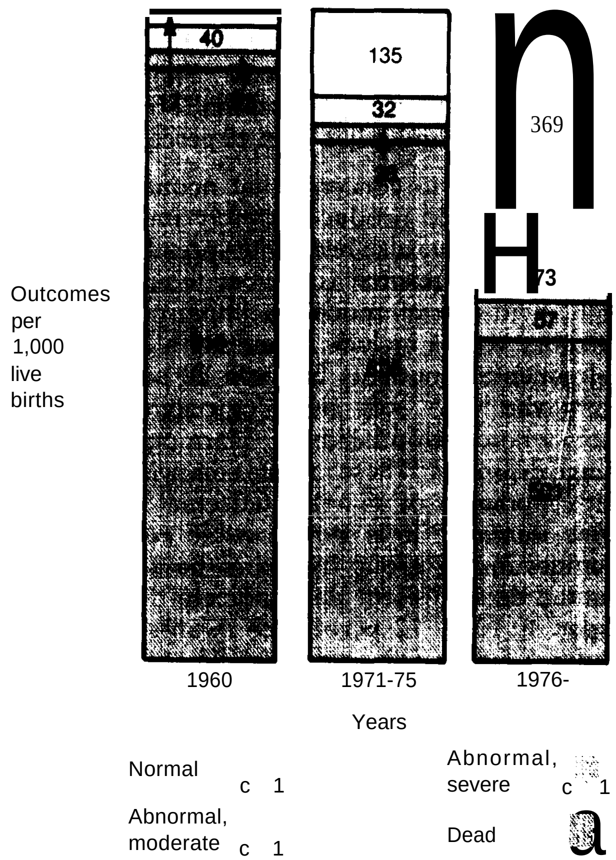
One finding of some concern is that the absolute number of seriously handicapped individuals may be increasing. For example, with birth rates at the 1978 level, intensive care nationwide produced about 350 severely handicapped individuals of birthweight 1,500 g or less who would have died in 1960 (see table 21). This figure must be balanced against the over 16,000 net increase in normal individuals at present surviving. It appears that the worst predictions—that most of the survivors of neonatal intensive care would be seriously handicapped—are by no means verifiable. The overwhelming majority of survivors are normal; a number have minor handicaps; and a smaller number are severely handicapped. In this sense, we conclude that neonatal intensive care is effective.

Figure 6.—Survival of Newborns, Birthweight <= 1,500 Grams



SOURCE See tables 17 and 19

Figure 7.—Survival of Newborns, Birthweight <= 1,000 Grams



SOURCE See tables 18 and 20

Table 21 .—Total Number and Distribution of Survivors, Birthweight <= 1,500 Grams, 1978

	Expected number[a]	Estimated actual number[b]	Net change
Normal ., .,	2,790	18,833	+ 16,043
Abnormal moderate,	5,425	4,069	– 1,356
Abnormal severe . . .	2,596	2,945	+ 349
Dead	27,979	12,904	– 15,075

[a]Expected number total births (1 500 g or less 1978 x outcomes estimated for births in 1960 (from flg. 6)
bEstimated actual number = total births (1,500 g or less 1978) x outcomes estimated for broths since 1976 (from fig. 6.)

SOURCE Text and previous tables

ECONOMIC ANALYSIS OF NEONATAL INTENSIVE CARE

CBA and CEA can provide some useful information on the economic implications of neonatal intensive care. With the expansion of NICUs, an increasing number of infants are being treated in Level 11 and III units. The high financial and human costs associated with neonatal technology and long hospital stays for the newborn make it necessary to examine and compare information on costs and effectiveness. Any CEA, however, is only as good as the data to be analyzed. The Imitations of the available information on neonatal intensive care have already been noted. In the following discussion, we tie together what is presently known about the costs incurred by and the outcomes expected for infants receiving neonatal intensive care. We summarize the characteristics of CEA and *re*view existing studies, and then we discuss the implications of applying a specific cost-effectiveness approach to the results of this case study.

In the strictest sense, neither CEA nor CBA is applicable to neonatal intensive care. CEA is primarily intended to measure and compare the costs of more than one way of arriving at similar outcomes. Ideally, such a method could be applied to comparisons between neonatal intensive care and prenatal prevention-oriented strategies, but the data needed to make such comparisons are lacking. Not nearly enough is known about causal relationships between changes in socioeconomic and nutritional status on the one hand and perinatal mortality on the other to predict the outcomes of targeted interventions. Even for risk factors (such as smoking and teenage pregnancy) that are causally related to neonatal disorders, the marginal costs and effectiveness of prevention strategies have not been carefully studied. FinaIly, since there **are** no alternative postpartum procedures to arrive at outcomes similar to those of modern neonatal intensive care, strict CEA does not apply. CBA also has severe limitations. In particular, placing dollar values on different human outcomes such as interrupted pregnancies, abnormal survivors, and even normal individuals is philosophically controversial—and in any case, it is difficult to arrive at satisfactory figures.

Nevertheless, CBAs and CEAs are useful for illustrating the economic implications of present intensive care methods for the newborn. Unfortunately, most of the analyses that have been done to date are simplistic. Many reports in the literature contain statements that the costs of hospitalization in an intensive care nursery are far less than the costs of life-long institutionalization of a severely defective survivor. Such analyses presume fully beneficial outcomes with treatment and totally unavoidable, severe handicaps without treatment. These assumptions are not justified.

A passage from the Governor of Pennsylvania's Health Task Force Report of the Committee on Infant Intensive Care (1974) illustrates the type of CEA of neonatal intensive care that is most often encountered (3):

> In the current economic climate, one must consider . . . the relative cost-benefits of an approximate 20-day hospital stay receiving intensive care (about **$2,000** to **$3,000)** versus a lifetime institutional stay receiving custodial care

(about $200,000 to $300,000), whose cost is usually borne by the State.

A similar one-dimensional view of cost effectiveness is found in Ross Laboratories' *Planning and Design for Perinatal and Pediatric Facilities* (109). That publication states that neonatal intensive care is "expensive to provide . . . but more expensive not to" ***(109).*** Institutionalization costs of $4,000 to $6,000 per year for 40 to 45 years for a brain-damaged child are contrasted to an average of 20 days of intensive care at $250 per day, or $5,000 total (109).

Neonatal intensive care may, in fact, be both cost effective and cost beneficial, but it is impossible to make that determination from such limited efforts which assume the effectiveness of neonatal intensive care and do not recognize all the possible outcomes, including death and morbidity.

A few thoughtful analyses have been conducted. The French Ministry of Health faced the question of how to reduce perinatal mortality before an extensive system of neonatal intensive care was in place (27). The Ministry applied a CEA to a variety of medical care options, including antirubella inoculation of young women, improved prenatal care, and NICUs. On the basis of its admittedly tenuous outcome **data, the Ministry designed a blend of the various approaches that was calculated to be cost effective** in terms of real governmental costs. The French analysis indicated that, as of nearly 10 years ago, NICUs decreased mortality but increased the incidence of handicap, making them relatively cost ineffective. In addition, two British investigators, Akehurst and Holtermann, have discussed the data collection and economic analysis basic to a thorough CEA of intensive newborn care (1).

Application of One Method of Economic Analysis to the Results of This Case Study

As detailed in the sections above, the existing literature and data on costs and effectiveness required extensive secondary analysis in order to generate a few tentative conclusions. The information needed for a complete CEA or CBA of neonatal intensive care includes a number of items not at present available (see table 22). For example, the amount of additional care required by survivors is not well established, let alone the costs of such care. Calculations would have to take into consideration such diverse elements as hospital and medical care needs of survivors after the neonatal period and the projected costs of treating such poorly understood complications as behavioral and learning disorders.

Table 22.—Information Required for a CEA or CBA of Neonatal Intensive Care

costs:
- Dollar costs of neonatal intensive care
- Dollar costs of additional care required by survivors
- Dollar costs of alternatives to intensive medical care
- Dollar value of intangible costs

Benefits/effectiveness:
- Likelihood of specific outcomes with intensive medical care and with alternatives to intensive care
- Dollar benefits over lifetime of survivors with each possible outcome
- Dollar value of intangible benefits

These limitations put the performance of an elaborate CEA or CBA beyond the scope of the present study. In order to discuss the findings of this study in an economic framework, we apply our results to a model previously developed by economist Marcia Kramer (70). Kramer's model was presented at a conference on Ethics of Newborn Intensive Care, cosponsored by the Health Policy Program, of UCSF in 1974. Her formula balances the actual dollar costs against the outcomes to be expected from different levels of intensity of newborn medical care. The net marginal costs of replacing less sophisticated newborn care with neonatal intensive care can thus be measured, making this a useful approach for the purposes of this study (see table 23).

The dollar values assigned by Kramer reflected the belief that normal survivors are cheap and economically productive; nonsurvivors are relatively inexpensive; and seriously defective survivors are both expensive and not productive. The cost of neonatal medical care is only the first cost to enter into the calculation. Postnatal direct costs included food, clothing, and education, and indirect costs included the mother's forgone earnings. After maturity, the expenditure flow reverses for a normal survivor as earnings outpace consumption. The severely abnormal survivor, however, is assumed never to generate income in excess of consumption. In addition, the abnormal survivor incurs costs exceeding normal consumption, including institutional custodial care, special education, and extraordinary medical care. Once the cost and benefit assumptions within categories are arrived at, one can examine the net costs of a variety of situations with different patterns of care and outcomes.

Table 23.—Kramer's Cost-Effectiveness Formula

(1) $$E = \sum_{i=1}^{3} P_{it}(N_i + C_{it} - B_i) - \sum_{i=1}^{3} P_{iw}(C_{iw} - B_i),$$

where:

E = expected net incremental dollar cost incurred by providing neonatal intensive care.

N_i = the medical care cost of neonatal intensive care itself for a child with eventual outcome i (usually $N_3 > N_2 > N_1$);

C_{it} = other direct and indirect dollar costs incurred during the lifetime of a child who is given intensive care at birth (t = treated) and whose eventual outcome is i (usually $C_3 > C_2 > C_1$);

C_{iw} = direct and indirect dollar costs incurred during the lifetime of a child who is denied intensive care (w = treatment withheld) and whose eventual outcome is i(C_{1w}=0 if euthanasia is the alternative to care, $C_{jw} = C_{it}$ otherwise);

B_i = dollar benefits yielded over the lifetime of a child with eventual outcome i($B_2 > B_3 > B_1$ = o);

i = 1: an infant death

i = 2: a normal survivor

i = 3: an abnormal survivor

P_{it}, P_{iw} = probability of outcome i given treatment decision t or w, respectively, where

$$\sum_{i=1}^{3} P_{it} = \sum_{i=1}^{3} P_{iw} = 1$$

(For this case study, P's are taken from figs. 6 and 7)

SOURCE: M.J. Kramer, Ethical Issues in Neonatal Care An Economic Perspective, in *Ethics Of Newborn Intensive Care,* A R Jensen and M. Garland (eds) (Berkeley, Calif.: Universlty of California, Institute of Governmental Studies, 1976)

One hypothetical pattern Kramer analyzed illustrated the outcome most feared: Mortality rates fell with intensive medical care, but most of the survivors were severely defective. That situation did not prove cost effective. Kramer also analyzed a second hypothetical pattern. It considered that medical care would lower mortality rates from one relatively low level to an even lower level, and the number of abnormal survivors would decline slightly. That hypothetical situation was found to be cost effective.

Based on the effectiveness material discussed in the previous part of this case study, it appears that the present situation is different from either of the two hypothetical patterns that Kramer presented. Our analysis shows mortality rates have fallen significantly, thereby improving the chances of survival in the very low birthweight groups. At the same time, the incidence of normal survivors has increased. Thus, the chance of a normal survivor now is many times greater than it was in 1960 (see figures 6 and 7). Although the incidence of serious handicaps has fallen, the rapid increase in survival means there may be a slightly increased chance of a very low birthweight infant becoming an abnormal survivor.

Applying Kramer's methodology (see table 23) to the data collected in this case study yields the finding that neonatal intensive care of infants weighing 1,500 g or less is marginally cost effective. Treatment of the subgroup weighing 1,000 g or less is not yet cost effective if the reported outcomes for 1971 to 1975 are used. When the most recent reports are used to estimate present outcomes, however, treatment of this subgroup becomes cost effective. The criterion for cost effectiveness is simply a negative net incremental dollar cost incurred by providing neonatal intensive care.

Data limitations are an inherent weakness of these cost-effectiveness estimates. For example, Kramer's cost and expenditure estimates were simply updated to 1978 dollar figures in proportion to changes in the consumer price index. More current dollar figures would improve the accuracy of the calculation. Furthermore, Kramer's model incorporated institutionalization costs for each abnormal survivor, but the recent trend favors care at home. A more careful examination of what percentage of infants are institutionalized, for how long, and for what

price would improve and perhaps change the net values. In addition to the data limitations, there are a number of methodological factors that could be examined and included to provide a more accurate and comprehensive estimate of the net incremental dollar cost of providing neonatal intensive care. In particular, use of a range of discount rates with a sensitivity analysis would provide a more sophisticated set of figures.

Even with the limitations discussed above, this illustration of a CEA highlights certain important aspects of the present return on the investment in neonatal intensive care. The characteristics of each birthweight group that led to a finding of "cost effective" or "not cost effective" raise considerations that go well beyond the financial ones. For **the** group weighing 1,000 g or less, the main reason that intensive care with outcomes such as those reported for the period 1971 to 1975 (see figure 7) does not turn out to be cost effective compared with outcomes reported for 1960 is that there was a small increase in the chance that a severely abnormal individual in this weight group would survive, That is, the costs of producing and caring for even a few severely abnormal survivors appear to be greater than the economic benefits gained by an eightfold increase in the rate of normal survivors (from 17 per 1,000 live births to 135 per 1,000 live births in that birthweight group) during the same period.

Thus, in this illustrative calculation, the increased number of normal survivors in the group weighing 1,000 g or less would not quite offset the high costs of the severely abnormal ones. However, even if a more sophisticated and precise cost-effectiveness calculation were to confirm this result, the legal and ethical issues that would be raised by any attempt to withhold care from all newborns of 1,000 g or less simply to avert the exceptional costs associated with the severely abnormal survivors could not be ignored. Because the lives of many healthy babies would be lost without intensive care, such a decision would never be made on cost-effectiveness grounds alone. This situation contrasts sharply with the hypothetical situation noted above, in which neonatal intensive care resulted in increased survival but was not cost effective because it uniformly led to defective individuals. In that hypothetical situation—which it appears we will not have to confront after all in the real world—the tradeoff was not between normal and abnormal survivors, but between fewer or greater numbers of defective survivors. Neither situation would be financially cost effective for society, but the factors to be weighed are quite different.

Neonatal intensive care for the group of infants weighing 1,500 g or less, although arguably cost effective, raises equally complex policy questions. The proportion of normal survivors in this group increased somewhat between 1960 and 1971 to 1975, while the ratio of normal to severely abnormal survivors increased dramatically (see figure 6). However, the data suggest that there may have been an increase in the absolute number of survivors with minor abnormalities. These survivors are productive individuals but are afflicted with minor degrees of handicap or illness. Thus, even though it might be cost effective to provide newborn care which results in this kind of outcome, the analysis is less than satisfying, because there is no adequate measure of the quality of life these individuals would attain.

Our analysis deals only with the question of whether neonatal intensive care is cost effective when compared with less intensive care of ill newborns. It does not address the larger question of whether such care is cost effective when compared with alternative programs to reduce the levels of prematurity and other risk factors in the population. That separate and even more complex question would require a thorough analysis of the costs and effectiveness of socioeconomic initiatives and prenatal medical care, followed by a comparison with the costs and outcomes of neonatal intensive care.

FEDERAL POLICIES RELATED TO NEONATAL INTENSIVE CARE[12]

Should the United States expand or limit the technology of neonatal intensive care? What Federal, State, and local policies encourage or inhibit rational planning of neonatal intensive care? These broad policy questions are being asked by a growing number of decisionmakers across the country. Public policies to date have emphasized both cost-based and charge-based reimbursement as well as regionalization of neonatal and obstetric services. Areawide planning assumes that the resources are scarce and should be allocated in the most efficient manner. With the present mix of reimbursement and regulatory controls, however, this policy may not be enforceable.

A major Federal policy regarding neonatal intensive care today is the National Guidelines for Health Planning promulgated under the National Health Planning and Resources Development Act of 1974 (Public Law 93-641). The neonatal resource standards set in the guidelines address regionalization by establishing a maximum number of beds per live births (4 beds per 1,000 births) and a minimum size of special care units (15 beds) (see table 24). These standards were largely based on the 1976 report of the Committee on Perinatal Health (32), the 1977 report of the American Academy of Pediatrics (4), and a review of Health Systems Plans.

Our analysis of utilization and supply data strongly suggests that closer examination of these figures by DHHS is needed. The present standard of 4 beds per 1,000 live births does not reflect adequate population-based need, only crude upper limits. Our best estimate is that only about half that number, or approximately 2.3 neonatal intensive care beds per 1,000 live births, probably are present in the United States today.

The combination of a generous per-birth bed figure and the 15-bed minimum unit size may result in an incentive toward marked oversupply. To meet the 15-bed minimum standard, many hospitals would have to choose among closing, consolidating, or expanding their units. With most of the United States well below the 4 bed per 1,000 live births minimum, hospitals in most health service areas could justify enlarging their units up to 15 beds. It would be very difficult for health systems agencies (HSAs) to deny requests to enlarge NICUs in areas that are well under the 4-bed maximum. Since at least 6 percent of births are probably receiving intensive care at the current bed level, a major increase in NICU supply would very likely represent excess capacity and promote increased utilization. This result would contradict the intended effect of the Federal policy behind the neonatal resource standard.

Medicaid funding, as described earlier,[13] is already exerting relatively tight controls over reimbursement of neonatal intensive care. By reimbursing for costs and not for charges, medicaid programs put a "lid" on unit expenditures for neonatal intensive care. The extensive cross-subsidization that results, however, suggests that further examination of medicaid reimbursement practices is needed.

Certain State medicaid limitations on reimbursement of neonatal intensive care create additional problems in providing care to newborns in low-income families. Medicaid reimbursement policies in Missouri, for example, cover only the first 21 days of newborn intensive care (48).

Medicaid insurance benefits for teenage and unwed mothers further exacerbate reimbursement problems. In January 1978, Butterfield (20) surveyed 30 States to determine the extent of their authorizations or State funding for perinatal services for the medically indigent. He found that only about half of the States provided coverage for perinatal care for the medically indigent. Those States with authorizations ranged from a high of $6 million in California to a low of $400,000 in Louisiana. The most common response was that there were no statutes providing State medical assistance for perinatal

[12] Written in October 1979.

[13] See section above on reimbursement for neonatal intensive care.

Table 24.—National Guidelines for Health Planning: Obstetrical and Neonatal Resource Standards

Standard	Purpose	Standard-specific adjustment	Definitional considerations	Special considerations
Obstetrical services				
• Planning on a regional basis with linkages among OB and neonatal services. • 1,500 births per year in Level II and III units. • 75% occupancy in units with greater than 1,500 births per year (Levels II and III).	Developing regional systems of care for maternal and perinatal health services reduces maternal, fetal, and neonatal mortality rates and improves development of scarce resources.	—	*Level I* unit—provides services for uncomplicated maternity and newborn cases. *Level II* unit—provides services for uncomplicated cases, the majority of complicated problems, and specialized neonatal services. Level III unit—provides services for all serious illness and abnormalities.	Special moral and ethical preferences may necessitate adjustments. The degree of complexity of patient needs should determine where, and by whom, the care should be provided. Established arrangements should provide for early access of high-risk cases and prompt referral among levels of care. In keeping with the national priority, consolidation of multiple, small OB units with low occupancy rates should be undertaken unless such action is undesirable because of needs to assure access and sensitive care.
Neonatal special care units				
• Planning on a regional basis with linkages with obstetrical services. • No more than 4 beds/ 1,000 live births in a defined neonatal service area. • A minimum of 15 beds for Level II or III units.	The regionalized approach reduces mortality rates and improves the development of scarce resources.	Areas with unusually high rates of high-risk pregnancy allows for adjustment upward. For a Level II unit, where travel time due to geographic remoteness is a hardship allows for adjustment downward.	*Level I* unit—provides recovery care. *Level II* unit—provides intermediate and recovery care and some specialized services. *Level III* unit—provides intermediate, recovery, and intensive care. "Bed" includes heated units and bassinettes.	Because centers often serve a patient load of more than 1 million, a defined neonatal service area should be identified by the relevant HSAs and State agency. Adequate communication and transportation systems including joint transfers of mother and child and maintenance of family contact should be developed.

Unit = a distinct and separate physical facility in an institution
HSA = health systems agency

SOURCE *National Guidelines for Health Plannning,* 42 CFR, sees 121203 and 121204, Health Resources Administration. DHEW, Mar 28, 1978

care for the medically indigent and that no such legislation was under consideration.

These medicaid policies result in the refusal of some physicians and hospitals to accept medicaid and low-income patients. To alleviate present inequities and to reduce infant mortality, the General Accounting Office has made the following recommendations for changing medicaid policies (48):

. . . ensuring that (1) Medicaid reimbursement rates for obstetrical and well-baby care are sufficient to encourage private providers to accept Medicaid patients, (2) more low-income women become eligible for Medicaid, and (3) States include coverage of at least HEW-specified minimum prenatal care services under their Medicaid program.

Maternal and child health services and crippled children's services operating under title V of the Social Security Act have encouraged regionalization and improved access to newborn intensive care. Federal funding for maternal and child health services under title V significantly increased from $85 million in 1974 to $206 million in 1977. Distribution of title V funds to States is based on a uniform allotment of $70,000 plus additional funding according to the number of live births. These funds must be matched by the State. The remaining half of maternal and child health funds goes for: 1) programs for mentally retarded children, 2) special programs of national or State importance, and 3) formula grants based on number of live births and per capita income (48). In order to receive title V funds, each State submits a Maternal and Child Health Plan that describes the State's needs and programs in five areas: 1) family planning, 2) maternity and infant intensive care, 3) women and infant care nutrition services, 4) children and youth, and 5) children's dental health (see table 25 for the proportion of Federal maternal and child health formula grant funds spent on newborn intensive care).

Title V also authorizes funds for crippled children's services. In some States, such as California, these funds have been used to cover intensive care costs. Unfortunately, no information exists on the prevalence of this practice. However, 37 out of 55 State Health Authorities reported purchasing inpatient care for mothers, infants, and children from the maternal and child health services program authorities (10). Since payments for neonatal intensive care are not reported as a separate category, it is impossible to collect total neonatal intensive care expenditures from the maternal and child health services program.

The improved pregnancy outcome (IPO) program, which began in 1976 as part of an overall HEW child health strategy, is a recent addition to title V programs. The IPO program was established to improve maternal care and pregnancy outcomes in States with high infant mortality rates. A requirement for funding is that a regionalized concept of prenatal and perinatal care be included in State plans. Funds may then be used to provide secondary and tertiary care referral systems, outreach systems, transport, provision of basic maternity care, identification of high risk pregnancies and infants, and outreach programs for pregnant teenagers. According to the recent General Accounting Office report on Federal efforts to improve pregnancy outcome, HEW awarded $9 million in IPO grants to 22 States, the District of Columbia, and Puerto Rico for 1978 (48). Each IPO State grant can total up to $400,000 annually for up to 5 years.

Another DHHS initiative to reduce infant morbidity and mortality is the improved child health program. In 1978, $3 million of maternal and child health funds and $1 million in title X family planning funds and National Health Service Corps personnel were made available to some 31 high-risk areas in 11 States. This money (up to $300,000 annually for up to 4 years) is to be used for coordinating comprehensive care to high-risk mothers and infants in areas with excessive morbidity and mortality (48).

Although DHHS's support for improving pregnancy outcome has increased significantly in the last 10 years, many complain that the programs are still grossly underfunded and fragmented. Some complain, for example, that money comes through too many different sources, sometimes bypassing State and local maternal and child health agencies. Others question whether the money is actually going to areas with the greatest need for reducing infant mortality (48).

Planning efforts by State and local maternal and child health agencies, crippled children's services agencies, and health planning agencies are increasingly overlapping. Each of the three agencies in each State is responsible for identifying infant health status needs, available services, and program alternatives to meet unmet needs. In some States, the three agencies have worked closely together to ensure consistent maternal and child health plans. For the most part, however, such coordinated planning is lacking, Whether this problem can be solved through informal, State-by-State means of communication or through specific mandates for integrated and consistent plans is a question that needs to be further addressed by both State and Federal agencies.

Table 25.—Budgeted Use of Federal Maternal and Child Health (MCH) Formula Grant Funds for Infant Intensive Care, by State, Fiscal Year 1978

State	Total MCH formula grant funds	Funds for program of projects[a]	Funds for infant intensive care: Amount	Funds for infant intensive care: Percent of funds for program of proiects[a]
Alabama	$ 4,807,268	$ 3,119,125	$ 200,000	60/0
Alaska	380,200	273,700	67,000	24
Arizona	3,180,901	1,174,315	103,611	9
Arkansas	3,080,400	1,421,300	221,000	16
California	11,254,203	5,516,191	372,683	7
Colorado	3,554,659	2,791,797	92,502	3
Connecticut	1,674,012	1,050,639	51,610	5
Delaware	869,282	329,900	50,000	15
District of Columbia	5,650,431	4,006,810	—	—
Florida	6,297,410	4,836,598	100,000	2
Georgia	6,476,053	3,897,400	884,196	23
Hawaii	1,087,320	937,112	25,000	3
Idaho	?,181 ,847	796,992	70,000	9
Illinois[b]		—	—	—
Indiana	3,766,399	1,521,256	266,459	18
Iowa	2,969,480	1,723,511	192,532	11
Kansas	1,838,237	1,014,343	122,061	12
Kentucky	4,860,198	1,669,946	356,475	21
Louisiana	5,606,425	380,631	147,402	39
Maine	1,447,000	697,000	115,000	17
Maryland	6,924,932	5,909,932	18,000	0.3
Massachusetts	4,793,097	3,717,338	72,324	2
Michigan	7,586,233	5,347,400	—	—
Minnesota	3,036,262	2,612,594	35,132	1
Mississippi	4,456,906	1,159,473	179,312	15
Missouri	4,397,076	2,280,276	98,985	4
Montana	1,267,960	494,222	20,000	4
Nebraska	1,860,220	1,432,880	61,477	4
Nevada	429,721	205,744	10,657	5
New Hampshire	759,000	659,000	55,000	8
New Jersey	3,475,146	1,415,685	—	—
New Mexico	1,299,429	810,179	66,583	8
New York	19,230,467	14,420,828	212,486	1
North Carolina	6,638,695	1,074,802	—	—
North Dakota	644,900	194,000	16,000	8
Ohio	7,960,502	3,996,444	184,539	5
Oklahoma	2,602,000	1,358,891	15,000	1
Oregon	2,571,356	998,268	275,000	28
Pennsylvania	9,292,751	5,679,083	119,740	2
Rhode Island	673,183	220,000	—	—
South Carolina	4,985,462	1,414,871	150,125	11
South Dakota	654,375	490,251	187,145	38
Tennessee	4,707,280	1,602,250	197,240	12
Texas	11,620,397	4,651,632	153,000	3
Utah	1,684,592	1,109,266	281,457	25
Vermont	423,927	423,927	36,542	9
Virginia	4,806,000	2,211,711	97,777	4
Washington	2,840,000	1,358,000	212,000	16
West Virginia	2,965,558	1,202,085	160,000	13
Wisconsin	5,309,900	2,364,900	768,500	33
Wyoming	472,876	106,500	—	—
Total	$200,351,998	$108,083,998	$7,121,552	1170 ‘

aSubtotal of MCH formula grant funds allocated to programs in the following five areas. 1) family planning, 2) maternity and infant intensive care, 3) women and infant care nutrition services, 4) chidren and youth, and 5) children's dental health
bIllinois has not returned questionnaire

SOURCE General Accounting Office, U S Congress, Better *Management and More Resources Needed To Strengthen Efforts To Improve Pregnancy Outcome,* HRD. 80-24 (Washington, D C GAO, Jan 21, 1980)

REFERENCES

1. Akehurst, R. L., and Holtermann, S., "Application of Cost-Benefit Analysis to Programmes for the Prevention of Mental Handicap, " in *Major Mental Handicap: Methods and Costs of Prevention,* Ciba Foundation Symposium **59** (Amsterdam: Elsevier Scientific Publishing Co., 1978).
2. Alden, E. R., et al., "Morbidity and Mortality of Infants Weighing Less Than 1,000 Grams in an Intensive Care Nursery, " *Pediatrics* 50:40, *1972.*
3. Allan, G., et al., *Report of the Committee on Infant Intensive Care* (Harrisburg, Pa.: Commonwealth of Pennsylvania, Governor's Health Task Force, 1974).
4. American Academy of Pediatrics, Committee on Fetus and Newborn, *Standards and Recommendations for Hospital Care* of *Newborn Infants, 2974-2977,* 6th ed. (Evanston, Ill.: AAP, **1977).**
5. ______, Committee on Fetus and Newborn and the Section on Perinatal Pediatrics, "Estimates of Need and Recommendations for Personnel in Neonatal Pediatrics, " *Pediatrics* 65:850, *1980.*
6. American Board of Pediatrics, Chapel Hill, N. C., personal communication, Apr. **23, 1980,**
7. American Hospital Association, *Hospital Statistics* (Chicago: AHA, **1977).**
8. ______ *Hospital Statistics* (Chicago: AHA, 1978). '
9. ______ *Hospital Statistics* (Chicago: AHA, **1979). '**
10. Association of State and Territorial Health Officials, *Services, Expenditures and Programs of State and Territorial Health Agencies,* NPHPRS publication No. **42** (Silver Spring, Md.: ASTHO, May 1979).
11. Banta, H. D., and Thacker, S., *Costs and Benefits of Electronic Fetal Monitoring: A Review of the Literature,* HEW publication No. (PHS) **79-3245** (Hyattsville, Md.: National Center for Health Services Research, 1979).
12. Barnett, H. L. (cd.), *Pediatrics (New* York: Appleton-Century-Crofts, Meredith Corp., 1972).
13. Basler, D. S., and Hager, D. E., *Planning and Design for Perinatal and Pediatric Facilities* (Columbus, Ohio: *Ross* Laboratories, 1977).
14. ______ Ross Planning Associates, unpublished study performed in conjunction with *Guide to Referral Centers Providing Perinatal and Neonatal Care* (Columbus, Ohio: Ross Laboratories, 1979).
15. Beauchamp, T. L., "Macroallocation and Policy Decisions, " lecture presented at the Conference on Life Prolonging Technology and Public Policy, Washington, D. C., Oct. 20, 1977.
16. Belenky, D. A., et al., "Is Continuous Transpulmonary Pressure Better Than Conventional Respiratory Management of Hyaline Membrane Disease? A Controlled Study, " *Pediatrics* 58:800, 1976.
17. Bhat, R., et al., "Immediate and Long-Term Outcome of Infants Less Than 1,000 Grams, " *Crit. Care Med.* 6:147, 1978.
18. Blake, A., et al., "Perinatal Intensive Care, " *J. Psychosom. Res.* 21:261, 1977.
19. Budetti, P., "Social Considerations of Health Policy for Perinatal Care, " speech delivered at Symposium on Progress and Problems in Perinatal Medicine, sponsored by the March of Dimes and University of California, San Francisco, Calif., Sept. 22, 1978.
20. Butterfield, L. J., The Children's Hospital, Denver, Colo., unpublished data from survey of Maternal and Child Health Directors, January 1978.
21. Calame, A., et al., "Psychological and Neurodevelopmental Outcome of High Risk Newborn Infants, " *Helv. Paed. A.* 31:287, 1976.
22. Calabresi, G., *Tragic Choices (New* Haven, Corm.: Yale University Press, 1977).
23. *California Administrative Code,* title 22, Health Facilities and Referral Agencies, register 75 (No. 24), sec. 70481—Intensive Care Newborn Nursery Service Definition, June 14, 1975.
24. California State Department of Health Services, Maternal and Infant Health Section, Berkeley, Calif., California perinatal data, 1977.
25. ______, Office of Statewide Health Planning and Development, Sacramento, Calif., "Annual Report of Hospitals, " 1977, revised March 1979.
26. Chance, G. W., et al., "Neonatal Transport: A Controlled Study of Skilled Assistance, " *J. Pediat.* 93:662, *1978.*
27. Chapalain, M. T., "Perinatality: French Cost-Benefit Studies and Decisions on Handicap and Prevention, " in *Major Mental Handicap: Methods and Costs of Prevention,* Ciba Foundation Symposium 59 (Amsterdam: Elsevier Scientific Publishing Co., 1978).