NEONATAL INTENSIVE CARE

A HISTORY OF EXCELLENCE

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CONTENTS

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FOREWORD

In 1960, the idea of having a special intensive care unit for newborns—a neonatal intensive care unit (NICU)—represented a developmental milestone for the field of neonatology. With the increased sophistication developed since then, doctors now are able to save the lives of many premature or desperately ill newborns who in the past would have died soon after birth. The result is that the U.S. infant mortality rate has shown a steady decrease since the NICU first came into widespread use a quarter of a century ago and, concomitantly, survivors have fewer sequelae.

The widespread access to NICUs based on the existence of regionalization has allowed the establishment of a national network of technologically advanced NICUs. Under regionalization, centrally situated hospitals maintain one or more NICUs available to all babies of high-risk mothers and to critically ill newborns referred from other hospitals located within a certain area. Babies born at hospitals not equipped with state-of-the-art facilities or without experts in perinatal medicine on their staffs are thus ensured access to the best possible neonatal care if needed. Regionalization represents nationwide access to health care in the true sense of the term.

Although the ability to sustain premature or sick infants is a significant medical advance, the ultimate goal is to eliminate the need for NICUs altogether. As with most, if not all, medical technologies, the benefits of neonatal intensive care are not achieved without certain risks. These risks run the gamut from inconsequential to deadly. Some premature babies born too small to survive on their own may have no apparent problems at first. Some, however, may survive only to suffer severe mental and/or physical handicaps later in life. Others, despite the best of neonatal intensive care, may not survive at all. In light of these critical risks, it is clear that, as always, prevention is far better than any cure.

Superficially, eliminating the need for NICUs appears to be relatively easy: simply reduce the number of low-birth-weight infants. But as any neonatologist or obstetrician knows, that is not a simple task. From steadily increasing numbers of births to teenage girls who receive little or no prenatal care, to smoking and other forms of substance abuse during pregnancy, the odds against successfully eliminating low birth weight are seemingly momentous. The rate of low birth weight births has remained virtually constant over the past 20 years.

A mere 30 years ago, a description of today's highly advanced state of neonatal care would have been met with disbelief. Yet we now know what is possible. Perhaps the next 30 years will bring about an equally miraculous decline in the incidence of low birth weight and its attendant problems. With education and superb prenatal care for all pregnant women, the goal is attainable.

The following essays present the history and development of the neonatal intensive care unit. Written by pioneers in the design and implementation of neonatal intensive care who shared their experience and expertise at the National Institute of Child Health and Human Development's Child Health Day symposium, they not only document the past, but give one hope for the potential of the future.

Sumner Yaffe, M.D.

Back to Contents

THE CARE OF PREMATURE INFANTS: HISTORICAL PERSPECTIVE

Dr. Lawrence M. Gartner
Dr. Carol B. Gartner

Although not an American, Dr. Martin A. Couney must be considered the American father of neonatology. Dr. Couney adopted the United States as his place of residence, and in a rather unorthodox fashion, this remarkable and unusual progenitor of those now involved in neonatology, brought to this side of the Atlantic Ocean the practical knowledge in the care of premature infants.

The actual year and place of Dr. Couney's birth are not known, but it is believed that he was born around 1860 or 1870 in Alsace, France or Breslau, Poland. He was educated in Breslau and Berlin and received his medical degree in Leipzig. In the 1890's Dr. Couney moved to Paris to study under his mentor, Pierre-Constant Budin. Budin had studied under Stephane Tarnier, an obstetrician who was a pioneer in the care of the premature infant and thus should be considered the grandfather of perinatology.

Although there were earlier attempts to build infant incubators modeled after chick incubators, Tarnier is generally credited with designing the first incubator for human infants. He put his new incubator into practical use in 1880 at the Paris Maternity Hospital.

Budin continued Tarnier's work, improving upon the original Tarnier incubator model. In 1896 Budin sent Couney to the World Exposition in Berlin to exhibit their latest incubator model.

Couney apparently added the idea of exhibiting live premature infants in the incubators at the Berlin Exposition, having perhaps heard about the activities of Alexander Lyon in Paris. The exhibit of six incubators and six infants was called the *kinderbrutanstalt,* the child hatchery. The hatchery was celebrated in comic songs and music hall gags. What began as a sober, scientific demonstration became a show that drew larger crowds than the Congo Village, the Tyrolean yodelers, and the parachute jump

located next to the hatchery.

Samuel Schenkein, a developer of exhibits, visited Couney and suggested that the incubator exhibit, which had become financially successful as well as popular, be moved to the Victorian Era Exhibition being held in London the following year. In that 1897 exhibit Couney used incubators made by Paul Altmann of Berlin. Altmann was an instrument maker for Robert Koch, discoverer of the bacterium that causes tuberculosis.

An editorial entitled "The Victorian Era Exhibition at Earl's Court" *(Lancet,* 1897) describes the facility as having a central room where the public viewed the infants in incubators, one side room used to wash and feed the infants privately, and another side room used as living quarters for the staff nurses and the wet nurses who supplied the milk for the babies. Mademoiselle Louise Recht, a neonatal nurse trained under Pierre Budin, led the nursing staff at the London exhibit.

The British would not permit Couney to exhibit British babies at the exhibit. Desperate because the show was about to open, Couney went to Paris and brought three wicker baskets of French babies across the English Channel via steamer to London. The show was an enormous success, establishing Couney's career as a showman.

The nursery, its physical structure, the use of wet nurses, and Louise Recht as head of the nursing staff remained the model Couney used over the next 46 years as he traveled around the world displaying premature infants in public exhibitions and charging admission to the shows.

Because these exhibits made big money, there were unscrupulous imitators of Couney's work. A letter published in *Lancet* warned against inexperienced and irresponsible imitators (Schenkein and Couney, 1897). Although an editorial that same year on "The Use of Incubators for Infants" (Lancet, 1897) compared the exhibition of human infants to that of five-legged mules, wild animals, clowns, and peep shows, Couney was not deterred, nor were his imitators. Couney's exhibitions were always set up in the sideshow areas of world's fairs and other events, although he would have liked his exhibit to be located in the scientific area.

Early Incubators

Strand magazine (December 1896) reported that Alexander Lyon of Nice in 1891 (at least 5 years before Couney exhibited) established the baby infant charity in Paris and charged 50 centimes admission. He also established operations in other cities where the cost of caring for the infants was paid by the city.

Using a design of his own, Lyon may have been the first to establish a premature infant incubator. Although the type of incubator initially used by Couney was probably the Lyon incubator, in subsequent exhibits it was called the Altmann incubator or the Couney incubator.

By 1898, Lyon incubators were apparently manufactured in New York by the Kry-Scheerer Incubator Company and sold to Dr. Joseph Bolivar DeLee, the inventor of the DeLee suction.

Dr. DeLee was an obstetrician, the founder of the Chicago Lying-In Hospital, and probably one of the two creators of academic obstetrics in the United States. In 1899, DeLee established an incubator station in the Chicago Lying-In Hospital, now at the University of Chicago. It's not clear what drove him to create the incubator station, which may well have been the first in a hospital setting. It might have been Couney's much publicized European success and his subsequent success in the United States. DeLee's 1900 annual

hospital report reads:

Incubator Station. In connection with the nursery, the Society has opened an incubator station for the proper care of weakly and prematurely born infants. We have two of the most modern improved incubators. And for the transportation of these delicate infants without exposure were from distant parts of the city and suburbs we have put in use an ambulance incubator, the first of its kind in this country. The work of this plant has been eminently satisfactory. And it has, in this short time, become an essential and valuable part of the institution.

In 1901 Dr. DeLee reported that 10 of the 12 infants admitted to the station during the year were saved. He also requested funds for enlarging the incubator station. He apparently received his money, because in 1902 he reported that the incubator station consisted of four improved stationary incubators and an ambulance. During that year all but one of the infants admitted survived.

DeLee continued his push by asking for a donation of $5,000 that would enable him to "establish an incubator station that would be commensurate with the needs of this great city."

His statistics for 1901 and 1902 showed that 23 babies were admitted during that period. The average length of stay in the incubators was 12.5 days, the longest 35 days, and the shortest 2 days. At the time of his report four had died and one was still in the incubator. Seven infants considered nonviable or moribund were separated out and were included in the statistics.

In 1898, 1 year before the Chicago Lying-In Hospital nursery opened, Couney moved to the United States and had an incubator exhibit at the Trans-Mississippi Exposition in Omaha, Nebraska. The infants for the exhibit allegedly were transported from Chicago to Omaha.

In 1900 Couney went to Paris to exhibit at the World Exposition, returning to the United States to exhibit at the Buffalo Pan-American Exposition the following year.

At the Louisiana Purchase Exposition in St. Louis in 1904, Couney had an elaborate two-story building with an inner courtyard. Although it is not certain, the babies were probably exhibited on the first floor, while Couney and the nurses lived on the second floor of the building.

Couney also exhibited at the Panama Pacific International Exposition in 1915 in San Francisco, California. These were elaborate exhibitions, costing a great deal of money to build, considering that they were used for only 1 or 2 years at the most.

Couney exhibited outside the United States at other world fairs too, including those held in South America and South Africa. In addition to these transient exhibits, he had several permanent summer exhibits that were much less elaborate than those he created for world fair audiences. His Coney Island New York exhibit, for example, existed with continuous summer operation (June through September) from 1903 until 1943, when public disinterest and World War II forced the show to close. He also had semi-permanent exhibits of the same type at Atlantic City, New Jersey, and for a shorter period of time, probably from 1912 to 1920, in Chicago’s White City amusement park.

Enter Julius Hess

Through his exhibit in Chicago, or perhaps even before, Couney came to know Julius Hess, professor and chairman of pediatrics at the University of Illinois and chief of pediatrics at the Michael Reese Hospital.

Hess and Couney became close friends. It was Hess, perhaps influenced by Couney, who brought premature infant care in the United States into an academic setting and into the medical literature. Hess independently established concepts of research on the newborn, conducted investigations, and developed new techniques. Despite their friendship, however, there is no evidence that Couney adopted Hess's new ideas. Couney kept an apparently unused Hess incubator in his exhibits in later years.

In 1914 Hess opened the premature unit at the Sarah Morris Hospital at Reese Hospital in Chicago, Illinois. An enlarged version was opened in 1922, setting in motion the overall concept of a regional center, designed as a large premature unit and created to serve the entire community.

Hess acknowledged his debt to Couney with the following statement in textbooks published in 1922 and 1928:

> *To Dr. Martin Couney I affectionately inscribe this effort to put into practice the experiences of a quarter of a century. The thoughts on premature infants were largely stimulated by his devotion to the welfare of these small infants.*

Many of the pragmatic aspects of premature infant care were transferred from Couney to Hess through two remarkable nurses—Louise Recht, also known as Aunt Louise, Couney's nursing director, and Evelyn Lundeen, Hess' nursing director.

Recht taught Lundeen the French techniques of gavage feeding and nasal feeding. Gavage feeding became the standard premature infant-feeding technique. The nasal feeding technique was never recorded in Hess' books, apparently because Lundeen did not believe that it worked or was safe. Nasal feeding is documented, however, in a film made in 1939 at Couney's New York World's Fair exhibit. In that movie, nasal feeding appears to work well. Recht is shown using a teaspoon with upturned edges to pour small quantities of milk into the nose of a premature infant who swallowed it without difficulty.

Lundeen also became closely involved with Couney's work, apparently working for him at the 1933-1934 Chicago Century of Progress Fair as the head nurse of his incubator unit. Lundeen said that she never liked the showmanship aspect of the work, but she did admire the care that was given to the babies, and she admired Louise Recht and Couney.

During the Chicago Fair Couney achieved his greatest national and international recognition. A *New Yorker* magazine profile of Couney offered some rather interesting insights (Liebling, 1936). The author wrote:

> *Dr. Couney did well at both seasons of the Century of Progress 1933 and '34. On good days, the concession took in as much as $1,500. It was sort of a jubilee for Dr. Couney because Chicago is the home of Dr. Julius Hess, the premature baby specialist.*
>
> *After the exposition the City of Chicago established a free premature station that is bigger than the one Dr. Hess has been directing the for so long (presumably the one at the Cook County Hospital).*
>
> *For once, Dr. Couney's incubator show received flattering attention from the medical associations, and Dr. Couney left Chicago bolstered in self-esteem as well as pocket.*

A personal communication in 1970 from Dr. Thurman B. Given, professor of clinical pediatrics at Long Island College Hospital in Brooklyn, New York and a close friend and supporter of Couney, perhaps best

puts Couney in perspective.

Given wrote:

> *Yes, I knew Dr. Couney for many years. He brought the first incubators into this country from France and established the nursery at Coney Island.*
>
> *He used only human milk and kept wet nurses for procuring it.*
>
> *He charged a small sum for carrying on the nursery.*
>
> *Most pediatricians, including me, disagreed with the commercial aspects of his undertaking. Many of the prematures he cared for came under my care after being discharged from his nursery. Thus, I decided to look into his establishment.*
>
> *Dr. Couney opened his books, and I soon found out he was not getting rich from his undertaking, and was very definitely saving very small prematures, who, in those years, could not have received good care in our hospitals.*
>
> *Thus, I began to send some prematures under 1,500 grams to him. He had a nurse trained in Paris to feed these small infants through the nostrils. I often watched her feed these infants with unbelievable skill.*
>
> *I also investigated to learn if Dr. Couney was ethical from a fee-splitting angle. He advised me that if an M.D. suggested such, and he said there were a few who approached him in that regard, he promptly invited them out of his office.*
>
> *Also, I found out that the late Dr. Julius Hess of Chicago had met Dr. Couney through Dr. Marfan of Paris. Hence, I wrote to Dr. Hess and told him of Dr. Couney's activities. He told me he only wished that Dr. Couney was in Chicago.*
>
> *During the first world's fair in New York in the 1930's, Dr. Couney established an incubator center at the fair that charged 25 cents admission.*
>
> *He asked me to establish a consultation committee of well-known pediatricians in New York City to work with the nursery at the fair. I was chairman and got several of the best-known pediatricians on the committee. Drs. Oscar Schloss, Carl Laws, Alexander Martin, and Hugh Chaplin were some of them. All thought he was performing an outstanding service. Dr. Hess came to look the nursery over several times.*
>
> *Dr. Arnold Gesell, the pioneering infant developmentalist from Yale, heard of the nursery at the fair. He wrote me and asked if he could arrange for him and Dr. Armatruda, his associate, to come and make observations. They came every 3 weeks, took pictures, movies by Dr. Paul Hartman, and in detail catalogued the movements and mannerisms of these very small infants while asleep, awake, and when being fed.*

Dr. Given also stated that all of the pediatricians connected with the nursery became great admirers of Dr. Couney. Although Couney did make money for a while, the world's fair undertaking left him completely insolvent and, in the end, he died a pauper.

During the summers of 1939 and 1940, Gesell went to the exhibit many nights after the fair closed to take

thousands of feet of movies of the babies and to observe them. This provided the basis for his book *The Embryology of Behavior* (Gesell, 1945). Although Gesell referred to Couney's contributions, he never identified the New York World's Fair as the site at which the movies were filmed. Following Couney's death in 1950, Gesell wrote a letter of praise to Couney's daughter, Hildegard, a nurse who worked at the exhibitions.

Although Couney may have been a flamboyant showman who became both rich and poor in the enterprise, there can be little doubt that he had a profound influence on the development of premature infant care and neonatology in the United States.

Back to Contents

CONCEPTUALIZATION AND INITIATION OF A NEONATAL INTENSIVE CARE NURSERY IN 1960

Dr. Louis Gluck

It is hard to imagine, in light of today's sophisticated facilities, instrumentation, techniques and skills applied to fetal-maternal-neonatal care, that there was a recent time when the medical specialties, maternal-fetal medicine and neonatal intensive care, did not exist. This, however, was the situation in October 1960 when we established the first known neonatal intensive care unit.

Prior to October 1960, there had been isolated instances when we and others had treated individual infants with what justifiably can be termed "intensive care." However, the actual organization of an ICU for prematures, newborns, and young infants began in October 1960, at Yale-New Haven Hospital. This development had a profound influence, in turn, on the development of fetal-maternal-neonatal medicine and on the subsequent direction of the field. At the time, it was a bold step forward since there were laws and proscriptions against such units and, further, there essentially were no precedents for techniques and organization for such care.

The following elaborates the considerations and events that led to the development of this first NICU.

Background

During the 1950's the mysterious fetus was untouchable, unseeable, unknowable, an invisible growing being with a heartbeat, whose weight could be estimated only by palpation (to within 100 percent error), who was visible only with x-ray, with no way to determine accurately size or maturity.

The care of newborns was divided. Sick term newborns and other young infants were given care on pediatric floors, often on open wards. Well premature infants were given care in premature infant nurseries. Sick premature infants were excluded from premature nurseries and were transferred either to pediatric floors or isolation rooms and cared for by ward nurses, usually obstetric nurses, who knew little or nothing about premature infants. This artificial division of care for infants in need of special care made no sense to me.

The Time Had Come

Victor Hugo stated, "Nothing is so strong as an idea whose time has come," and by the late 1950's it was clear to me that the founding of an NICU indeed was an idea whose time had come. At that time, early ICU's including cardiac and rudimentary pediatric ICU's, were coming into existence.

Unfortunately, the establishment of an NICU was impossible in the late 1950's. Laws throughout the United States prohibited the mixing of term and premature, well and sick, medical-care and surgical-care, and outborn and inborn babies. These laws were generated by the justifiable fear of the spread of *Staphylococcus aureus.* In the 1950's and 1960's, "staph" infections were common, often rampant, in newborn nurseries.

All too frequently, infants leaving the best hospitals colonized nasally with staph would be readmitted within a short time with a major systemic infection with staph, such as pneumonia or meningitis. Frequently introduction of a colonized baby into a home would be followed by an outbreak of pustules and boils among family members.

This fear determined nursery construction as outlined in an article by Eichenwald and Shinefield (1960), *figure 1*, and the conduct of nurseries, as described by Wheeler (1960) *figure 2.* It even caused the U.S. Public Health Service to issue recommendations to reduce the pool of colonized and susceptible infants in nurseries with the extensive use of antibiotics (USPH & NAS, 1958). They stated:

Figure 1. *Construction and Maintenance of a Nursery*

- Few Infants Sharing Common Air Supply (4-6 per unit)
- Wide Separation Within Unit (30 sq. ft. per 4-infant unit)
- Positive Pressure Ventilating System Supplying 12-15 Draft-Free Clean Air Changes Per Hour
- Cohort or Rotation System of Admission and Discharge Plus "Overflow" Nursery
- Care in Exposure to Attendants:

  Contact with least number of persons needed for adequate nursing care

  Same nurses caring for same infants during stay

  Frequent cultures of attendants to detect carriers

  Exclude from contact with infants anyone with suspected staphylococcal disease or any respiratory infection

Figure 2. *How to Improve the Conduct of Our Nurseries*

- Eliminate Nurseries
- Isolate Each Infant in His/Her Own Air-Conditioned Room
- Rotate Nurseries
- Make Hospital Stay Short
- Eliminate Use of Common Equipment (bathing tables, etc.)
- Decontaminate Common Equipment Which Cannot be Eliminated (bottlewarmers, disposable covers for scales, etc.)
- Remove Ill Personnel
- Treat Nasal Carriers with Bacitracin or Neomycin Nasal Jellies
- Remove Personnel who Harbor Same Strains Causing Lesions
- Satisfactorily Dispose of Diapers and Soiled Linens
- Use Individual Thermometers, Soap, Oil, etc.
- Wash all Vernix
- Control Dust
- Use Ultraviolet Light
- Use Air Conditioning (apply mathematics of exchange transfusion to bacteria in the air)
- If Breakout Occurs, Convert Susceptibles to Non-Susceptibles by Administering Appropriate Antibiotics in Therapeutic Doses to All Babies in the Nursery

It is possible to protect infants from colonization by administering an effective antibiotic in full therapeutic doses to all infants beginning immediately after birth and continuing until after discharge. Antibiotic prophylaxis of this type effectively prevents colonization of the infant's nose and thus his skin...

The Epidemiology of Staphylococcus

In 1959, at Stanford, a study was designed to challenge the predominant theory about the spread of staphylococcus in nurseries (Simon, Yaffe, and Gluck, 1961). Epidemiologists were convinced that virtually everything in a nursery, including personnel and fomities (down even to sink traps), contributed to a pool of staphylococci that sailed through the air and infected babies. This theory held that the only way to safeguard the infant was either by extreme isolation or, if that failed, extensive antibiotic use, and led to the legislation creating the isolation techniques used throughout the United States.

The study was set up to evaluate and accomplish two things. First, to prevent the skin and umbilical cord from becoming colonized by staphylococcus, at or shortly after birth, in order to prevent the more dangerous and more permanent nasal colonization. Nasal colonization had been identified as the source of other infections, both in the infant and among family members exposed to an infant with nasal colonization. Second, to institute scrupulous handwashing before and after touching infants, which was believed to be the key to preventing the spread of the organism once colonization had occurred.

These considerations led to our now infamous findings on hexachlorophene *(pHisoHex)*, namely that no matter what the age, size, or condition of a baby, whether the child is outborn or inborn, colonization of the skin and the cord is preventable by washing the baby with *pHisoHex,* and that organisms are not spread

if caregivers' hands are washed between babies (Simon, Yaffe, and Gluck, 1961; Gluck and Wood, 1961; Gluck and Wood, 1963). Brain lesions attributable to the use of hexachlorophene were found later in a very few sick babies under 1,400 grams (Powell et al., 1973; Shuman, Leech, and Alvard, 1974).

The concept that it is safe to mix infected and noninfected babies in an NICU initially was very difficult to sell. Although the studies started at Stanford showed that colonization could be prevented effectively by washing babies with the antiseptic suspension and by washing the hands, permission to develop an NICU at Stanford was denied.

A Beginning

In 1960, I was appointed Director of Neonatal Services at Yale University with the understanding that I would be allowed to develop an NICU. Armed with information from the studies at Stanford and from studies I initiated at Yale, the NICU at Yale-New Haven Hospital opened its doors on October 15, 1960. It is believed to be the first such unit.

Full-term and prematurely born babies with problems (both inborn and those we transported to our unit), including babies infected with staphylococcus; premature growing babies; babies with surgical conditions; and those with any medical problems were admitted into the unit.

In the beginning there were few good NICU techniques and no NICU standards to follow. Although we helped develop original equipment and techniques, many ideas came from discussions with others, especially those about mechanical ventilation and appropriate monitoring of infants.

The NICU actually began in the premature nursery described by Cooke (1954). The general conditions in the premature nursery-turned NICU included incubators augmented with servo-controlled infrared heat, a narrow hall, and only one sink.

The groundwork for success in forming a pioneering NICU included openness of mind on the part of the caregivers. At Yale this unwittingly had been done along several fronts many years prior to my coming. For example, Gesell's work on child development, that began with premature infants, had originated at Yale. Rooming-in was first introduced in 1944 by Dr. Edith Jackson at Yale. In 1949, she began putting babies on the gurney with their mothers, skin-to-skin, for 1 to 1 1/2 hours after birth. The term "bonding" was not yet used. Although it was against the law, in about 1955, she began allowing parents into the premature nursery to see and handle their babies. This began a new era at Yale, perfect for experimentation and work with the care of newborns and prematures.

Shortly after the establishment of the NICU, the local medical community began to raise ethical questions about the mixing of babies. There was widespread concern on the part of many medical experts who thought it was unsafe, fearing that babies would die from staphylococcal epidemics. However, with the washing technique, we reported on our unique experience of 25,000 consecutive deliveries without a single staphylococcal lesion (Gluck, Wood, and Fousek, 1966).

Babies who previously had been considered hopeless were being saved, including some with brain damage. This time the local medical community questioned the wisdom of saving these babies, often believing that it would have been better to have let them die. This area is still one of much discussion.

There were few well-established techniques for neonatal intensive care. Newborn infants were ventilated with adult ventilators and EKG machines were used as intermittent heart monitors in neonatal intensive

care, circa 1961-1962. Later it was learned that without proper grounding of electrical equipment, a drop of electromotive force could occur across an infant causing electrocution. The need for universal grounding of equipment and assurance that electrical equipment used on infants did not leak current was not yet understood. Although many basic techniques for day-to-day care of NICU patients had evolved from premature infant nurseries, the conversion of these techniques to help us deal with increasing numbers of highly sick infants was a slow, difficult practice.

One major, positive innovation that could be adapted anywhere was developed at Yale during this time, and this was the large-room concept for the care of premature infants. This was a direct assault upon the cornerstone of classic nursery epidemiologic practice to contain staph, which was the small space/few infants in the space concept. Owing to the limited space in the premature nursery we had converted into an NICU, the department of obstetrics ceded an adjacent 4-bed ward which we converted into a 20 bed NICU addition.

Except for the smallest prematures with respiratory distress syndrome, all other infants with problems were admitted into the large room, including those with diarrhea. We never registered a morbidity as a result of this supposed epidemiologic breach. We showed that, with proper technique, it was perfectly safe to mix infants in large numbers in one area.

Another major policy contribution of this era at Yale was the formation of a *de facto* perinatal center, with close cooperation and near assimilation of obstetric and neonatology service. Two of the major reasons for closeness were Dr. Edward Quilligan, chairman of the department of obstetrics, a major contributor to maternal-fetal care, and Dr. Edward Hon, who rightly is considered the Father of Electronic Fetal Monitoring.

A great break occurred in December 1964, when the very ill newborn grandson of the late tycoon, Charles A. Dana, was admitted to the NICU with persistent fetal circulation, respiratory distress syndrome, and pneumonia. Shortly after the baby was well and discharged, a large check arrived from Dana, who ultimately donated more than $1 million.

Almost immediately upon receipt of Dana’s gift, a physically new perinatal center was planned, but did not open until early 1967. The delay occurred when the first three Yale architects resigned due to state and national (under Hill-Burton) hospital architectural regulations that prohibited large-room nurseries. The architect who eventually designed the center was not a hospital architect and was not familiar with the regulations. A compromise was made with the Hill-Burton regulations by dividing the 40 beds among four rooms, one of which accommodated 20 babies (Gluck, 1973).

Many innovations in care and architectural design and function originated in the Yale Newborn Special Care Unit. One was the origin of the Q2/suction/electricity/compressed air facilities in the ceiling. By eliminating the wall-bound facilities and placing them in the ceiling, this left the total floor space unencumbered; the incubator and/or crib placement thus was totally flexible, and could be positioned for the convenience of the nursing staff. Unfortunately although convenient and flexible, this arrangement also was expensive and unsightly.

Another innovation was the regional concept used for each work area. Each area was supplied from its contiguous cabinets. This way nurses did not have to walk more than half the width of the room for supplies. Each infant’s station, in another innovation, was set up as an independent intensive care unit, with its own dedicated infant monitors, infusion equipment, ventilators, and supplies. This allowed the nurse giving an individual infant care maximum convenience, intensity, and flexibility of care.

Conclusion

The unique opportunity to organize and establish the first NICU was made possible by the help of many persons including the dedicated nurses, the many house staff, fellows, and colleagues who encouraged and supported the development of an NICU before it was permissible.

Back to Contents

REGIONALIZATION OF NEONATAL INTENSIVE CARE

Dr. L. Joseph Butterfield

Regionalization of health care is not new; it has been advocated in some form for nearly 60 years. But the implementation of the concept has not fared well in the diversified United States health care delivery system (Lewis, 1977).

The establishment of the first premature infant center at Sara Morris Hospital in Chicago in 1923 marked a new era of concern for the sick newborn (Hess and Lundeen, 1941). The work of Dr. Julius Hess and nurse Evelyn Lundeen became the standard for premature infant care as other centers were developed in the United States. Dr. Louis Gluck established the first newborn center in the country at Grace New Haven Hospital in New Haven, Connecticut in 1960 (Gluck, 1977). These hospital components of regional perinatal care have grown extensively in 25 years (Basler, 1982). Each regional center has developed a set of outreach tools in the shape of transport systems, outreach education programs, and funding mechanisms.

The 1965 Regional Medical Program targeted heart disease, cancer, and stroke as conditions that would benefit from regionalization, but the program suffered and died and was relegated to being yet another great American idea (Diamond, 1974).

The Comprehensive Health Planning Law (PL. 89-749) was developed to promote plans for health care but produced more hope than result. The law lacked enforcement power and local health planning groups spent enormous quantities of time dealing with local political issues.

Regionalization of perinatal care can be traced to the development of premature infant centers in the United States during the 1930's and 1940's. While the centers spread throughout the country during this period, there was little in the way of standards of perinatal practice as we now know it, and the impact of the centers on infant mortality in the United States was modest.

A 1977 authoritative publication on regionalization failed to mention regional perinatal care, bringing to light the low priority given to the perinatal care movement by professionals in the health planning field (Lewis, 1977).

Many past efforts to establish regional programs to improve access to care, increase the number of physicians, or to relocate professionals have been federally funded, but the bulk of support, staffing, and systems development came from diverse sources. Public, private, and voluntary funds flowed through a pluralistic network of agencies, institutions, and organizations in a disjointed and uneven approach.

There have been positive consequences of regionalization on neonatal outcome. Regional perinatal

education, expanded role nursing, interhospital care, shared services, and systems development have all benefited from this concept.

At the national level, the infant mortality rate (IMR) in the United States had been a nagging embarrassment. From 1950 to 1965 the IMR remained almost static at 25/1000. In the next 18 years, as regional perinatal care developed in most regions of the country, the IMR fell by 60 percent to a record low in 1983 of 10.9/1000. Most of that improvement was for newborns in the first month of life as all but three states reported neonatal mortality rates less than 10/1000 in 1983 (Reinhold, 1980).

It is impossible to point out every factor in the improved outcome of newborns in the United States and dangerous to cite any single factor as the reason for the trend (Shapiro, 1981; *Lancet*, 1974). However, it can be argued that regionalization of care has been one of the more important factors.

The premature infants that I encountered as a medical student, intern, and subsequently as a pediatric resident presented monumental challenges. Early studies of the premature by Dr. Lula Lubchenco, her mentor, Dr. Harry Gordon, and others shifted the management of the premature infant from custodial caretaking to scientifically-based concepts of care. The establishment of the Premature Infant Center of Colorado General Hospital in 1947 was a western landmark in the history of premature infant care in the United States.

My interest in regionalization was sparked during some casual exchange on rounds at the University of Colorado about nutrition and the fact that the problems of hunger in underdeveloped nations would never be solved by providing just a few more meals. Progress solving the root issue of malnutrition was a social, economic, and political matter. Transposing that thought to the care of the premature infant and the sick newborns, the idea of a systems approach emerged. By adding an organizational dimension, the possibility and logic of regional perinatal care came into focus.

During my years as a fellow and a junior faculty member at the University of Colorado Medical Center (UCMC), my interests in premature infant care turned to the concept of community outreach. Two events strengthened that concept. First, working with the UCMC United Way Fund Drive opened my eyes to the many community agencies that serve people in need. Second, was the logistics involved in transporting a 3-pound baby 167 miles by air transport from Southern California to the UCMC. Although the logistics were mammoth the experience was exciting.

In 1959, Dr. C. Henry Kempe and Dr. E. Stewart Taylor hosted a conference at the Brown Palace Hotel in Denver. Pediatric and obstetric directors of premature infant centers throughout the United States were invited to participate. As an impressionable fellow and bystander, it was disturbing for me to observe how little interaction had taken place between the pediatric and obstetric leadership. Unfortunately the proceedings of that landmark conference were not successfully recorded for posterity.

In 1963, at the Aspen Conference on Perinatal Biology, the absence of obstetricians was quite obvious, as was the general perinatal approach at that time. Clearly neonatal people were leading the way.

The quarter-century from 1956 to 1981 brought more progress and more promise for the premature infant than any similar previous quantum of time. Not only has the technology and treatment ascended in quantity and quality, but the kinship of psychological and sociological programs has brought the history of premature infant care full circle (Korones, 1981).

Eli Ginsberg defined regionalization as "a form of resource allocation or service delivery rooted in

geography." In the introduction to *Regionalization and Health Policy* (1977), Ginsberg cited the resources in the present health system that might be responsive to political and consumer pressures to improve access to more cost-efficient and care-effective health services. Physician distribution, capital expenditures, and patient flow are integral elements in his thesis that regionalization "should be able to yield greater social benefits to more citizens through improved allocation and the use of resources than is now the case." According to Ginsberg there are crucial considerations if regionalization is to work. "A mechanism must exist that assesses the health needs of a population within a defined area and responds by altering the existing resources and/or adjusting the supplies of health personnel, facilities, and equipment" (Ginsberg, 1977).

The Newborn Center of Children's Hospital in Denver opened in February 1965 with a commitment to providing a comprehensive newborn intensive care service on a referral basis for hospitals in the Rocky Mountain and Great Plains regions. As director of the Newborn Center my immediate commitment was to sick newborns on a regional basis but with a perinatal orientation as a long-term goal. From the onset, programs and policies were developed to improve the outcome of pregnancy.

In 1966 a Ross Conference on Intrauterine Transfusion was held in Aspen, Colorado, jointly sponsored by the University of Vermont and the Children's Hospital in Denver. This conference was an extension of the 1963 Aspen Conference on Perinatal Biology, which resumed as the Aspen Conference on the Newborn in 1967.

At the regional level, service, education, communication, and transport systems were developed to combat the excessive neonatal mortality rate of the 1960's. Colorado ranked number 45 in neonatal mortality and only five states had a higher neonatal mortality rate. By 1982 Colorado shared the number one spot with Arizona and Hawaii.

In about 1970, I was a guest of the Committee of the Fetus and Newborn of the Canadian Pediatric Society which had worked with the Society of Obstetrics and Gynecology of Canada to develop a statement on regional perinatal care (Swyer, 1970). Armed with the articulation of a policy statement from Canada and fresh with enthusiasm for regionalization based on a young working model in Colorado, I introduced the concept of regional perinatal care to the AMA Committee on Maternal and Child Care (CMCC).

A subcommittee met and composed a policy statement on regionalization/centralization of perinatal care that was presented to the AMA Board of Trustees and House of Delegates. In 1971 the policy statement was adopted as AMA policy. This was a landmark day in American medicine and a futuristic statement on perinatal medicine by the AMA.

This policy was transmitted to the American Academy of Pediatrics (AAP), the American Academy of Family Physicians (AAFP), and the American College of Obstetricians and Gynecologists (ACOG) for their endorsement and support. Over the next 2 years each organization reviewed the policy and endorsed it.

Concern arose that the policy statement on regional perinatal care had stimulated many hospitals to enter neonatal care without consideration of a regional plan. A need for guidelines or standards for levels of perinatal care was apparent.

In May 1972, Dr. Sprague Gardiner, president of ACOG, made two critical decisions that, no doubt, have had crucial long-term impact. First, he stated his belief that the professions that provide the bulk of perinatal care should take the leadership in any developing guidelines. Second, he made it clear that

professions should take the initiative in inviting other parties to collaborate. Dr. Gardiner called a special meeting of representatives from the four major provider organizations: the AMA, the AAP, the AAFP, and the ACOG. The National Foundation/March of Dimes was invited to participate. The representatives agreed that the time was ripe for an ad hoc group to convene to accept the task of implementing the landmark policy.

In August 1972, a planning meeting was held and task forces were set up on facilities and services, personnel, and implementation and financing. One of the people assigned to the task force on facilities and services was Dr. Gardiner, who was chairman of the Committee on Perinatal Health. His clinical savvy, his keen organizational skills, and his uncanny political sense made him an ideal leader of the campaign that had begun to improve the outcome of pregnancy. Gardiner's leadership and advocacy was recognized by the AAP when an award from the Section on Perinatal Pediatrics was presented to him at a plenary session of the AAP's annual meeting in 1981.

After 4 years the committee's report was published (National Foundation/March of Dimes, 1976). Entitled *Toward Improving the Outcome of Pregnancy* (TIOP), the monograph provided a working set of broad-based guidelines to be used by professional organizations and consultants. The report evoked enormous interest and was quoted extensively in the generation of state, regional, and national health policies. It was given national recognition in the "Standards for Obstetric and Newborn Services," published in the March 28, 1978 *Federal Register*. During the 1970's the elements of regional perinatal care were begun, stated, developed, and put into practice throughout the United States.

In 1973 the 66th Ross Conference on Pediatric Research paid special attention to discussion of model programs for the care of high risk mothers and their infants (Sunshine and Quilligan, 1974). Model programs were already in existence in nine states. Examples of city, state, and regional programs and the essential components of personnel, instrumentation technology, and systems of maternal and neonatal transport provided insight to developing programs.

It has indeed been incredible years for maternal and newborn care.

Back to Contents

INTERRELATIONSHIP OF RESEARCH AND CARE IN NEONATAL INTENSIVE CARE UNITS

Dr. Mildred Stahlman

Research has always provided the scientific rationale for the practice of medicine. Without it, patient care would be based only on empiricism and limited to the information gleaned from personal trial and error, the teaching of one's own preceptors (also based on empiricism), or on the acts of charlatans who deceive the patient deliberately. Inquisitiveness is one of our most important attributes and, fortunately for our profession, is still encouraged among our students and colleagues. Nowhere has research had a more direct and spectacular effect on patient outcome than in the neonatal intensive care unit.

Thirty years ago normal-term newborns were adequately cared for in newborn nurseries. Their outcome, already good, has changed little since then. Premature infants, both well and sick, were placed in premature infant care nurseries, where larger, non-sick infants were likely to survive if they did not acquire nosocomial infections.

Sick infants, both term and premature, and very immature infants had an appalling mortality and morbidity as birth asphyxia, respiratory distress, Rh disease, infection, and other disorders took a terrible toll. Oxygen was withheld from hypoxic, gasping infants for fear of retrolental fibroplasia. Many infants, especially those who had surgical procedures precluding oral feeding, died of inanition, as glucose in water proved an inadequate substitute for protein as a sole caloric source.

Research on newborns had been largely related to normal infants, to those with infectious diseases, and to a few specially designed clinical trials in normal prematures such as those by W.A. Silverman. Studies tested such things as temperature regulation and humidity, but the technology needed to study adequately the physiology and biochemistry of normal prematures, sick prematures, and sick term infants was not available. Every new bit of scientific information was exciting and each eventually resulted in modifying the care of these babies and their outcome.

The first NICU's were begun by people already trained in research techniques, usually with animal models or in adult patients. Unwilling to accept the status quo, these pioneers designed nursery settings where scientific measurements could be carried out even on very sick and very premature infants. The early nurseries were usually backed up by an animal laboratory or basic biochemical laboratory. Data from these laboratories was taken back to the bedside for clinical trial and, if successful, became part of the nursery regimen.

A good example of this intimate interrelationship of laboratory, clinical research, and patient care and how it has directly impacted on improved outcome in the NICU, is the long sequence of studies on the biochemical and physiological consequences of asphyxia that led to ways of reversing those changes. At one time oxygen was introduced into the stomach for resuscitation and alternating hot and cold tubs were used in the delivery room. It also took a long time to realize that hypothermia was more harmful than protective to the severely asphyxiated infant.

The seminal studies of Apgar and James on the correlates of the biochemical and clinical evaluation of asphyxia, followed by a series of studies in primates by James, Dawes, Adamsons, and others led to the principles defining the use of prompt and proper ventilation and oxygenation, through an endotracheal tube, if necessary; the value of circulatory maintenance through cardiac resuscitation; and the use of buffers to restore the acid-base balance to normal. An understanding of the circulatory consequences of asphyxia in fetal lambs with redistribution of blood flow in the diving seal pattern, as demonstrated by Rudolph and colleagues, also led to conceptual changes in our understanding of target organs such as lungs, gut, and kidneys.

Studies on transitional circulation began in human newborns with Lind, Eldridge, Cassels, James, and Rowe, following the animal modeling by Barcroft, Barron, and Dawes. The adverse effects of asphyxia, hypoxia, acidosis, and hypovolemia were documented in these animal models and then, using adapted techniques, in human infants. Management strategies were designed and tested, based on scientific information rather than anecdotal success or failure. This led to further studies on the circulation in infants with demonstration of large left-to-right shunts through the ductus arteriosus in many of the sickest infants. The discovery of prostaglandins and their possible role in ductal patency *in utero* led to finding that administration of prostaglandin synthetase blockers induced ductal constriction in sick premature infants. These and other studies have also changed the approach toward the management of infants with hyaline membrane disease with symptomatic ductal patency.

Grunwald and Avery found that infants dying from hyaline membrane disease had abnormal pressure

volume curves indicative of high alveolar surface tension. This led to a cascade of important studies on surfactant, its biochemistry and biophysical properties, the consequences of its presence or absence, its cell of origin, its ontogenic history, and finally, its induction in borderline states of lung differentiation. Ongoing studies of surfactant replacement are showing promise with more research yet to come.

Ventilators vs. Respiratory Distress

Based on principles used in the management of older individuals with poliomyelitis in Scandinavia, and on the experience of those used to treat neonatal tetanus with positive pressure ventilators in Cape Town, the use of ventilators in infants with respiratory distress began in the United States and in Canada in 1961. The introduction of the long-term use of both positive pressure ventilators by Swyer and negative pressure ventilators in this country was accompanied by studies of their effects on blood gases and circulation, and outcome of patients with differing degrees of disease severity.

Studies of almost every organ system in these infants became possible once they were able to be kept alive for prolonged periods of time. Much of what is now known as intensive care—the use of intravascular catheters, blood or transcutaneous gas monitoring, arterial pressures, heart rate and temperature monitoring, water balance, metabolic status, and a myriad of other facets of care—was developed as the result of research after the success of assisted ventilation.

Gregory's important demonstration showed us that adding constant distending airway pressure would improve outcome in hyaline membrane disease. This led to a new series of studies on the mechanics of breathing, both on and off ventilators, and improved our understanding of the ventilatory needs of the sick infant while at the same time trying to avoid the excesses and disastrous results of such treatment. Clinical trials of new approaches toward assisted ventilation continue and more needs to be learned before high frequency ventilation can be recommended for routine use in the NICU.

Another classic example of the impact of research on newborn care is bilirubin. Lucey's studies in primates established that indirect bilirubin crossed the placenta, but direct bilirubin did not. Studies of bilirubin transferase, the enzyme needed for conjugation and excretion of indirect bilirubin, its relationship to gestational age, and its induction by such compounds as phenobarbital helped us recognize patient risk and improved patient-care management. Odell's studies of bilirubin binding and tissue distribution also led to changes in exchange transfusion criteria and protocol. Studies showing that photodegradation products of bilirubin were harmless to infants opened a noninvasive management strategy that has been invaluable in the smallest and sickest NICU infants.

Another dramatic example of the interrelationship of research and NICU's is the development of parental alimentation as a substitute for oral intake in nonfeeding infants. Many infants suffering from calorie and protein malnutrition, poor wound healing, and failure to thrive or grow succumbed to secondary infection after prolonged periods on intravenous (10 percent glucose and water). The prototype was a term infant with gastroschisis, requiring multiple surgical procedures with gradual closure of a large abdominal wall defect over many weeks. The mortality rate was about 50 percent, usually from secondary infection at 4 to 6 weeks of age. Studies by Dudrick showing that solutions containing amino acids are safe and promote growth and wound healing in older people, prompted many careful and important balance studies and studies of amino acid composition, in newborn humans and animals.

These studies led to sequential modification in our parental solutions. They also led to dramatic changes in morbidity and mortality in many infants, including those with gastroschisis, gut atresia, chronic respirator

dependence, and other conditions.

There are many other examples of how research and patient care have gone hand-in-hand in the NICU. Not every step has resulted in an automatic success story. The importance of careful and objective evaluation of each new modification in management, preferably in a model system, followed by controlled clinical trials, must still be emphasized.

Learning From Change

What can we learn from a recital of past changes in patient care resulting from research? First, research implies uncertainty. In every clinical trial the physician-scientist asks the parent or the patient to share the risk, however small, in testing a new idea, a new mode of therapy, or a new approach to management. In some cases this may not be better than the old way of doing things, but actually worse—not just in short-term effects but also in long-term effects apparent only years later. The development of committees for the protection of human subjects addresses this problem, but in reality they only assure informed consent. In the long run, it is the intellect, the integrity, and the conscience of the physician-scientist that must fulfill the tenet *primum non nocere.*

Second, advances in science move slowly. Each piece of new information builds on all of the previous ideas, data, and trials provided by others. No new information, however trivial it may seem at the time, is wasted if it is true.

Third, the transition of new ideas into clinical care, even those proven superior by careful trials, is a slow process. We are creatures of habit and old ways die hard. Colleagues, editors, nurses, and hospital administrators must be convinced before new approaches are put into practice.

Fourth, the role of the physician-scientist in this relationship is crucial and must be nurtured and preserved. We are told that the physician-scientist is a disappearing breed with increasing pressures of hard-to-get research money and private-practice incentives driving the individual toward other career goals. It takes many postgraduate years to simultaneously become a competent neonatologist and a competitive scientist. Recent trends in funding for research training make it increasingly difficult to achieve this status. This is a national crisis and steps must be taken to assure that, if motivation can be restored, training funds for career physician-scientists will be available.

Fifth, and finally, so many new changes have dramatically improved outcome in the NICU that public expectation has been raised unrealistically for salvaging the unsalvageable, saving the hopeless. The public must be kept informed of current limitations and of the continuous need for research support. We, on the other hand, must never accept these limitations as permanent. They are only a temporary resting place, a place for seeing into the future. Tennyson wrote in *Ulysses,* "Yet all experience is an arch wherethrough gleams that untravel'd world, whose margin fades forever and forever as I move."

So let it be with us.

Back to Contents

NURSING RESEARCH CONTRIBUTIONS TO IMPROVE NICU CARE

Dr. Mitzi Duxbury
Dr. Lawrence R. Adams

Historically, nursing did not separate the care of infants and children from the care of mothers until recently. Most graduate programs in nursing that deal with the care of mothers, infants, and children are still called "maternal and child health programs." Nursing has always found it difficult, and perhaps unwise, to separate the care of the infant child from the care of the mother and family. Within this framework, nursing has made significant and enduring contributions to care of the newly born infant. Nursing has always provided the caring part of the healing process and has had a major impact on maintaining and promoting good health. Healthy babies come from healthy families. It is in this realm of health promotion and maintenance that nursing has made its most important contribution to the improvement of care for mothers and babies.

*Historical Perspective**

Nursing, or some primitive form of nursing, has been involved in the bearing, nurturing, and rearing of children long before recorded history. Midwives are mentioned in the *Book of Genesis* and are present at the second labor of Rachel and at Tamar's delivery of twins. Hippocrates instituted the first formal training of midwives five centuries before the birth of Christ.

The wealthy women of the Middle Ages might have been tended by both nursemaids and midwives. The newborn baby often roomed with the mother in the 15th century obstetric ward. The medieval midwife developed her skills from observation and practice, having borne children of her own. In difficult labor the midwife asked the advice of a physician, but he did not participate in the delivery and under no circumstances would he have examined the mother.

Sixteenth century woodcuts show women delivering their babies while seated, a common practice in Europe, using either an obstetrical chair or a V-shaped stool.

In the 18th century infant mortality stood at around 50 percent throughout Europe. In London between 1730 and 1750, three-fourths of all children who were christened died before the age of five. England's Queen Anne, who surely must have received superb care for the time, lost 18 children in early infancy.

A Hogarth etching of the 1700's shows "dropped" babies, those left outside to freeze or starve. The killing of infants was not uncommon among the masses in the 18th century. Unmarried mothers sometimes disposed of their newborn children so they could earn a living as wet nurses.

A few hospitals for foundling children—unwanted babies or babies orphaned in a plague—were established in the 1700's. An example was the Paris Foundling Hospital, incredibly dirty and overcrowded, where, on average, 90 infants were admitted during the day and 70 bodies were carried out at night.

Wealthy women often put their children in the care of wet nurses, many of whom had lost their own children to disease. These wet nurses often passed the disease on to the newborns. During the late 18th century it was the fashion among French upper class to bottle-feed their babies. Bottle-fed babies got sick from contaminated milk and water; the death rate was three times that of breast-fed babies.

Nursing entered its dark ages at about the same time the rest of Western civilization emerged from them. A commandment that declared a women's place to be in the home compromised the status of midwifery In the place of the nursemaid and midwife appeared "nurses" recruited from ex-prisoners, drug addicts, and women whose age rendered them unfit to solicit men.

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*We wish to credit Dolan (1978) and Kalisch and Kalisch (1978) for some of the historical material in this paper. Permission to reprint this material from Mead Johnson and Company, Evansville, Indiana.

Neonatal Pioneers

In the middle of the 19th century the fresh spirit of Florence Nightingale emerged. To call her the founder of modern nursing is to speak modestly of her accomplishments. She was far more: humanitarian, rebel, architect of social reform, builder of hospitals, and pioneer of nursing education. Her direct contribution to neonatal nursing was profound but almost incidental in terms of the transcendental nature of her contribution to nursing as a whole.

Florence Nightingale brought science and sanitation, common sense and fresh air—both figuratively and literally—into the depressing confines of the sick room. Her approach to nursing was "to put the body in the best condition to heal itself," the basic theory still advocated today.

Among her accomplishments was direct intervention to make childbirth safer. Having collected and analyzed data on puerperal fever, she documented the following relationship: When 8 beds are in one hospital room, 8 per 1,000 die; when 4 beds are in one room, 4 per 1,000 die. She noted that mortality rates for mothers and babies in hospitals were higher than those in most homes, even in homes informally cared for or unclean.

Florence Nightingale died in 1910 at the age of 90, having seen the arrival of the first female physician and the advent of teaching hospitals based on many of her ideas. Nurses in these hospitals received a thorough grounding in every aspect of medicine and hospital administration.

Another nursing pioneer, Lillian D. Wald, graduated from the New York Hospital Training School for Nurses in 1891, and subsequently conceived and implemented a nursing service that helped the sick-poor of the Lower East Side of New York City. With her classmate, Mary Brewster, in 1893 she opened what became the world-famous Henry Street Settlement on the top floor of a tenement in the Lower East Side.

Settlement workers provided nursing services at both the Settlement house and in the homes of sick and poor immigrants in New York City. Public health nurses at the Settlement made great efforts to visit the homes of their clients to assist them with child care and to instruct them in bathing, hygiene, diet, and infant care. Showing a mother how to properly feed, bathe, and care for a newborn often saved the child's life.

In 1910 the maternal death rate in the United States was third highest among countries keeping such records. At that time perhaps half of all births in the United States were attended by midwives. It was a period of unrestricted and heavy immigration, and the midwives usually shared race, nationality, and language with their clientele. The problems posed by poverty (inadequate housing, diet, health care) called for new institutional responses to large-scale social problems.

Social advances in the United States culminated in the Sheppard-Towner Act of 1921. Specifically

designed to provide Federal funds for improving maternal and infant care, the legislation enabled hundreds of nurses to make home visits, provide health education, and encourage prevention of disease. The 1915 death rate for infants, 100 deaths for every 1,000 births in the United States, dropped to 69 deaths per 1,000 by 1928. In 1929, when the Sheppard-Towner Act expired, 45 states and Hawaii had established child health agencies; 700,000 expectant mothers and 4 million infants and preschool children had received care; and there were almost 3,000 permanent prenatal and child health centers.

Although the Sheppard-Towner Act brought about improved health care, many women still did not have access to hospitals and many remote rural areas and city tenements were not being served. Mary Breckenridge, a resourceful public health nurse and midwife, set out to remedy the problem in the isolated mountainous areas of southeastern Kentucky. In 1925 she set up the Frontier Nursing Service in an area of Kentucky where approximately 200 inhabitants struggled on the edge of survival. Travel was by horse or mule. With her small corps of nurse-midwives, Breckenridge provided public health nursing and midwifery, infant and child care, instruction in diet and proper health habits, preventive care, and inoculations. By the end of the 1920's, Sheppard-Towner money was directed toward the training, licensing, inspection, and supervision of midwives in 14 states.

In 1932 the Metropolitan Life Insurance Company sent a physician to examine the first 1,000 cases of the Frontier Nursing Service. He found that complications were lower in number and severity than among the general population of Kentucky and that no maternal mortality had occurred as a result of childbirth services offered by the Service. The doctor wrote:

> *The type of service rendered by the Frontier nurses safeguards the life of mother and babe. If such a service were available to the women of the country generally, there would be a saving of 10,000 mother's lives a year in the United States and 30,000 less stillbirths and 30,000 children alive at the end of the first month of life (Dublin, 1932).*

The Frontier Nursing Service survived as a unique institution although the idea failed to catch on due to a variety of political, social, and economic conditions. In 1929, just when they were getting started, the Service was abruptly canceled when the Sheppard-Towner Act was allowed to lapse. Joining forces with political conservatives, the American Medical Association had criticized the act as "wasteful and extravagant, unproductive of results and tending to promote communism." (American Medical Association, 1930.)

The Nation soon found itself in the midst of the Great Depression. This calamity threatened the security of the Nation's children. Available medical care for children diminished and malnutrition increased dramatically. As political leaders drafted legislative responses to this massive economic disturbance, the advice of several farsighted consultants on the needs of children was heeded. Former opponents of proposals affecting the health of children, perhaps reacting to the changing times, did not attempt to block the new legislation.

The result was title V of the Social Security Act, "Grants to States for Maternal and Child Welfare," signed into law on August 14, 1935. Title V established a Federal-State partnership to promote maternal and child health and to provide wide-ranging services for handicapped children. Among the many services, title V provided for the establishment of bureaus or divisions of maternal and child health care as major components of health departments in every state, expansion of public health care nursing through the maternal and child health care program, creation and support of public child welfare services, and a national medical care program devoted to the problems and care of handicapped children. Many programs

also included substantial participation by private organizations. Originally administered by the Children's Bureau, title V programs still exist as part of the Public Health Service and operate in close cooperation with the National Institute of Child Health and Human Development to improve the quality of health services available to mothers and children.

Another Turning Point

No history of nursing in neonatology is complete without mentioning the contributions of Margaret Higgins Sanger, a public health nurse who spent the greater part of her life promoting the cause of voluntary contraception. After giving birth to three children during the early years of her marriage, she was drawn to the plight of the unfortunate. First, to oppressed workers in industrial factories such as those in Lawrence, Massachusetts, and then women, rich and poor, who could not control the size of their families. When she was 29 she nursed back to health a friend who had tried to abort herself. Sanger's friend asked her physician what she could do to keep from having more children. The doctor responded with a remark to the effect that the woman's husband could sleep on the roof. Three months later the woman, again pregnant, again tried to abort herself. Sanger was at her friend's bedside when she died. In the following years, she cited the experience as the turning point in her life.

It was Sanger's involvement in public health maternity care that drew her attention to the fact that free birth control information needed to be made available to all. She searched for books on birth control, but none were available. The Comstock Act of 1873 had forbidden the mailing of birth control literature. Anthony Comstock and his disciples whom President Grant had armed with pistols and a posse for a war against pornography and the First Amendment, were celebrated for their raids on places that sold materials classified as obscene under guidelines as whimsical as any lynch law. These materials included advice on birth control.

Because contraception was accepted and practiced in Europe, Sanger went to France to learn more about birth control. Upon her return to the United States she published *The Woman Rebel,* a periodical giving precise, detailed, and accurate information on contraception and family planning. In 1916, in Brooklyn, New York, she opened the first birth control clinic in the United States. On the first day more than 150 women came to the clinic for information on birth control. Ten days after the clinic opened, Sanger was arrested, taken before a judge, sentenced to 30 days in a workhouse, then physically restrained and taken off to be imprisoned and subsequently force-fed for she refused to eat while locked-up.

Sanger's efforts place her among the titanic figures whose influence fostered increased neonatal survival and healthier mothers and babies.

Emerging Technology and Techniques

At the turn of the 20th century a French physician named Pierre-Constant Budin discovered that incubator care was associated with improved survival of premature infants. One of Budin's pupils, Martin Couney, brought the idea of heat maintenance for premature infants to the United States. Couney is credited with advances in incubator design to care for these infants as well as premature feeding techniques.

A disquieting result of Couney's practices was the finding that premature infants, taken from their mothers for care, tended to have more adjustment problems than other infants. An increased incidence of idiopathic failure to thrive was seen weeks or months after being discharged from the hospital. In some cases the children were returned to the hospital battered.

In the past 15 to 20 years, nurse researchers and others have explored this phenomenon in terms of overall behavioral organization of preterms and other newborns and the subsequent development of caregiver-infant interaction patterns. During this time nursing research contributed to our improved understanding and practice in a variety of ways. Although it is impossible to cite all of the authors, much less share their findings, a few representative studies follow:

Gene Anderson

Nonnutritive Sucking Opportunities:
A Safe and Effective Treatment for Preterm Neonates

Even though fetuses often suck nonnutritively, premature infants receive few, if any, sucking opportunities during their first days of life. Yet Anderson found that nonnutritive sucking appears to have many beneficial effects (Anderson, Burroughs, and Measel, 1983). Settling of restless infants is facilitated, respiration becomes deep and even, arousal levels are optimized (both sleeping and alert phases), passage of meconium occurs (indicating that sucking facilitates completion of the gastrointestinal cycle), neuromuscular coordination improves, and the infants seem to nurse better. It may also aid circulatory adaptations postbirth (Anderson, 1983).

Fifty-nine premature infants were randomly assigned to a treatment group or a control group. Treatment infants were offered a pacifier during and following every tube feeding. Control infants received routine care. Data collection continued until hospital discharge. Treated infants began bottle feeding 3.4 days earlier and gained 2.6 grams per day more than controls. Furthermore, they were discharged 4 days earlier than those in the control group. The number of complications also favored the treatment group (Anderson, Burroughs, and Measel, 1983; Measel and Anderson, 1979).

This research has been replicated and extended twice. At the University of Miami, Tiffany Field studied premature infants in collaboration with Anderson (Field et al., 1982). The 30 treated infants went home 8 days sooner than the control infants. A second study was conducted at the University of Pennsylvania by Judy Bernbaum in consultation with Anderson and Measel (Bernbaum et al., 1981). In this study the treated infants went home 7 days sooner than controls. Intestinal transit time was 15.5 hours for the treated infants and 27 hours for the controls, a finding with important implications concerning the control of necrotizing enterocolitis.

Kathryn Barnard

The Premature Infant Refocus Project

The work of Kathryn Barnard has made a major contribution to improved infant care with her research effort, the "Premature Infant Refocus Project." This project was concerned with studying the impact of early extrauterine environment on the premature infant. There were two aspects to this project. The first was an evaluation of the effects of a treatment designed to support the neurological and behavioral organization of preterm infants. Premature infants in the first days of life were given temporally patterned vestibular (rocking) and auditory (heartbeat) stimulation. This resulted in improved functioning and more rapid development than preterm infants experiencing routine hospital care (Barnard and Bee, 1981; 1983).

The second aspect looked at developmental changes in maternal interactions with term and preterm infants. Preterm and term infants at 4, 8, and 24 months of age were observed during simple and difficult

teaching sessions with their mothers. At 4 months the preterms had lower levels of responsiveness and task involvement than the term infants, although the mothers of preterms provided equal or heightened levels of stimulation compared to mothers of terms. At 8 months the preterms were no different from term infants in task involvement, but the preterm mothers' levels of involvement had remained stable or declined. At 24 months the mothers of preterms showed lower levels of positive messages and reported lower levels of involvement with the child than did mothers of term infants. It appears the pattern for mothers of preterms is initial compensatory enthusiasm for the parenting role in the first year, followed by signs of burnout in the second. Thus, the study reveals differences in mother-infant interaction patterns with term and preterm infants that persist at least throughout the first 2 years of life (Bernard, Bee, and Hammond, 1984).

Rosemary White-Traut

The Effects of Multimodal Supplemental Stimulation on Premature Infants

Rosemary White-Traut's research has involved the effects of multimodal supplemental stimulation of premature infants in NICU's on their weight gain and length of hospitalization. She employed the Rice Tactile Stimulation Protocol, consisting of 10 minutes of gentle massage in a cephalocaudal progression, followed by 5 minutes of vestibular rocking once daily. Concurrent with the massage and rocking were auditory stimuli (talking or singing) and visual stimuli *(enface* position, attempted eye contact) by the examiner. The results suggested that infants may experience some improvement in weight gain and a shorter hospitalization after receiving treatment (White-Traut and Tubeszewski, 1986). Furthermore this stimulation technique is successful in bringing premature infants to the developmentally more mature quiet-alert state that is optimal for interaction with caregivers (White-Traut and Pate, 1985).

Ramona Mercer

Studying Factors That Impact on the Maternal Role

Ramona Mercer's research focused on the factors occurring during the first years of motherhood that have the greatest impact on maternal role attainment and what factors, separately or in combination, facilitate or deter attainment of the maternal role. Teenagers, ages 14 to 19, were interviewed at 12 periods during their first year of motherhood to study the impact of motherhood on the mothers and their infants. Four periods appeared critical for the infants—the first days following birth, 1-month old, between the third and fourth month, and between the sixth and ninth months.

The youthful mothers' failure to identify and respond sensitively to a growing infant's needs during the first year suggests the need for close follow-up. Extensive social support is needed, either via foster parent care for the infant or, in some situations, for herself, or in special residential homes (Mercer, 1980).

Mitzi Duxbury

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*Reduction of Sleep Disruption in Neonatal Intensive Care Units***

The progress of 159 high-risk infants was monitored by Dr. Duxbury in two NICU's following introduction of a treatment protocol at one of the units to minimize sleep disruptions for caregiving. In the experimental unit caregiving was provided on a delayed, clustered basis contingent upon an infant's

aroused state. At the control site routine caregiving practices were maintained. This resulted in a dramatic effect on length of stay. Infants at the experimental site were discharged, on average, 10 days earlier during the treatment phase than in a pretreatment phase, whereas no significant differences were found at the control unit in the corresponding periods.

Results indicated that the experimental treatment was feasible, easily implemented, low in cost, not unduly disruptive of nursing or medical care in the NICU, and related to improved outlook and earlier discharge of high-risk infants. Such a reduction in length of stay for even half of the low-birth-weight babies born each year could result in a savings of millions of dollars per year (Duxbury, Adams, and Henly 1985).

**Funding for this project provided by the Robert Wood Johnson Foundation, Grant number 7073.

Mitzi Duxbury

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*Causal Models for Nurse Turnover in Neonatal Intensive Care Units****

The purpose of this study was to develop causal models explaining three employment withdrawal behaviors of NICU staff nurses: turnover, burnout, and absenteeism. It was hoped that development of these causal models would serve as the basis for intervention programs designed to reduce withdrawal behavior among staff nurses in NICU's. Nurse turnover in the NICU is positively correlated with neonatal mortality.

Causal models of the LISREAL type (also referred to in quantitative social science literature as structural equation models, or covariance-structural analysis) were developed, based on extensive questionnaire data obtained from 563 nurses at 16 NICU's.

The results support several generalizations. Leadership characteristics of the head nurse and neonatologist were correlated with staff nurse perceptions of disregard of their concerns by the hospital administration. This administrative disregard is highly predictive of the degree to which the nursing staff felt exploited. Turnover and absenteeism, however, were difficult to predict. Burnout was explained well by the model. Work factors outweighed social and family support as an explanation of all the withdrawal behaviors. Perception of the job market was an important variable. Turnover and absenteeism were more predictable when nurses perceived an open job market, while burnout was more predictable when nurses perceived a closed job market (Duxbury, 1982).

***Funding provided by the Maternal and Child Health and Crippled Children's Service Research Grants Program, Bureau of Community Health Services, HSA, PHS, DHHS, Grant number MC-R-270439.

Other Researchers

Other significant contributions include those of Marie Scott Brown on assessment of sensory capacities in infants and children, Mary Margaret Brown on parental concerns about infant behavioral organization, Ann Burgess on sexual abuse of children, Jacqueline Chapman on stimuli and motor patterns of preterm infants, Juanita Fleming on methadone-addicted infants, Debra Hymovich on the assessment of impact and coping among the parents of chronically ill children, Gail Mallory in exploration of the effect of auditory

stimulation on preterm behavior, Ida Martinson on home care for the dying child, Margaret Miles and Melba Carter on assessing parental stress in intensive care units, Mary Neal on overall organizational behavior in the preterm infant, Ruth Rice on sensorimotor stimulation and development in high-risk infants, Paula Meier on preterm breast feeding, and Olive Rich on support systems.

These pioneers and others have made unique and priceless contributions that are vital to the improvement of maternal and child health care practices. These observations should evoke a renewed appreciation of the role nursing research has made and will continue to make in promoting the health and well-being of newborns and families.

Back to Contents

IMPACT OF NEONATAL INTENSIVE CARE ON INFANT OUTCOMES

Dr. George Little

Many individuals have provided leadership in neonatal intensive care in the past 30 years. One of the individuals who focused attention on infant outcomes is Dr. Lula Lubchenco. Dr. Lubchenco and others believed that scientific scrutiny of outcomes of neonatal intensive care was critical. They constantly asked the questions that still force us to prove or disprove the Null Hypothesis as it relates to neonatal intensive care. Does neonatal intensive care have an impact? If so, is that impact positive, negative, always present, sometimes present, independent, or interdependent?

The questions are older than 30 years. In reporting on a 10-year follow-up of premature infants born between 1947 and 1950 and admitted to the Colorado Hospital Premature Infant Center, Lubchenco and her colleagues' first reference is to Julius Hess (Lubchenco et al., 1963). The paper to which they refer appeared in *Pediatrics* and describes the premature infant studies that he started in 1922 (Hess, 1953). The article includes a blueprint complete with isolation and graduate rooms, mentions a clinic for instruction for mothers of premature babies and, most important, singles out nurses for recognition.

Hess states, "Much has been accomplished in our time in lowering mortality and morbidity among premature infants..."

Ten years later Lubchenco drew attention to the issue of morbidity in not quite as positive a fashion and without her usual subtlety, commenting:

> *The foregoing data leave little doubt about the high incidence of residual handicap in small premature infants born between 1947 and 1950 and cared for at the Premature Infant Center in Colorado. These handicaps include visual defects primarily due to retrolental fibroplasia, brain damage, retarded growth, social and emotional problems.*

She concludes, "A high incidence (68 percent) of central nervous system and visual handicaps was found in a group of small premature infants 10 years after birth" (Lubchenco, 1963).

Analyzing the Data

These fundamental questions about mortality and morbidity following neonatal intensive care remain, and should remain, in our minds. However, there is ample evidence today to discount any question or doubt that neonatal intensive care has resulted in increased survival. We usually resort to birth weight specific

data in our analyses, and in the past 10 years many authors have addressed the issue of neonatal mortality, usually focusing on the low-birth-weight population (those weighing less than 2,500 grams). Combined data from several studies in England and the United States demonstrate apparent improvement in birth weight specific data in the 1960's and 1970's. There is no evidence at this time suggesting regression in survival data in the 1980's although there is concern that the rate of improvement may be decreasing.

Lubchenco is also known as the person most responsible for stimulating and organizing our thought on the relationship between birth weight and gestational age. Her paper, "The University of Colorado Birthweight/Gestational Age Worksheet," or Lulagram is considered a classic and still used widely (Lubchenco, Searle, and Brazie, 1972).

Other studies using both birth weight and gestational age demonstrate that differences in neonatal intensive care mortality can be more critically delineated. Time, institution, or population-based comparisons can be made. We have shown, for example, that global comparisons between nurseries by birth weight alone can be erroneous because of population differences, but birth weight-gestational age evaluation can correct for some of the differences (Philip et al., 1981).

In a study in North Carolina from 1968 to 1977, it was found that better perinatal care accounted for the majority of improvement in the neonatal mortality rate (David and Siegel, 1983). It was calculated that 34 percent of improvement was attributable to changes in the birth weight-gestational age make-up of the population.

Through an analysis of natality statistics between 1970 and 1980, it was ascertained that there was an apparent selective improvement in the weight of term infants (Kessel et al., 1984). When gestational age was considered, they determined that the number of small newborns fell by 14 percent but that the number of prematures decreased by only 7.1 percent.

Another study of infants in Georgia, born between 1974 and 1981, found that few infant deaths, especially in the 500-999 gram group, may have been postponed beyond the neonatal period (Buehler, Hogue, and Zarro, 1985). However, neonatal intensive care did lead to significant survival of the baby weighing less than 1,500 grams.

The organizational aspects of neonatal intensive care systems have received some attention. An article in the *Journal of the American Medical Association* (McCormick, Shapiro, and Starfield, 1985) discussed the decrease in neonatal mortality and its apparent relationship with neonatal intensive care and the effect of maternal-fetal transport in increasing deliveries of high-risk pregnancies in proximity to neonatal intensive care units. In other words, they evaluated the impact of systematic delivery of perinatal health care.

Sinclair, Torrance, Boyle, and associates (1981) pointed out that neonatal intensive care programs have never been tested experimentally. In their opinion, "Much of the nonexperimental evidence supporting their value is based upon the experience of referral units and does not measure the impact on the population they serve."

A paper analyzing New York City's low-birth-weight infant mortality rates (Paneth, Kelly, and Wallenstein, 1982) stated that the authors were influenced by Sinclair's paper with questions he raised regarding the analysis of the effectiveness of different levels of care. They demonstrated that in the New York City system, birth at a Level III center lowers neonatal mortality in low-birth-weight infants to a rate below that of those infants born in Level I and II centers. They also noted that this association cannot be explained by differences in social or demographic status, prenatal care, or medical complications.

Changing Public Perception

Given the positive impact of neonatal intensive care on mortality, there is legitimate reason to change our public discussion of this subject. Rather than mortality, perhaps we should be talking about survival and using survival charts (Little and Philip, 1983).

Unfortunately we cannot be as specific and emphatic in our review and discussion of the relationship between neonatal intensive care and morbidity. The aforementioned less-than-encouraging data of the 1950's have given way to other reviews that are somewhat more positive. Much of the literature focuses on neurodevelopment handicaps and their relationship to low birth weight. Certainly, given the overwhelming statistical predominance of low birth weight in the neonatal intensive care population, such evaluations are appropriate. Individuals studying the cost-effectiveness of medical technology have concluded that the prevalence of neurodevelopment handicaps seems to be decreasing (Budetti et al., 1980).

On the other hand, we are continually bothered by observations and comments by others suggesting that a specific entity such as retrolental fibroplasia or, in more recent terminology, retinopathy of prematurity (ROP), may be reemerging in epidemic form (Phelps, 1981). One of the pioneers of neonatal intensive care has been constantly challenging our consciences by using ROP as a probe (Silverman, 1980). Some of the bad dreams of the past 30 years are in fact reality.

The relationship between changes in survival, that is, mortality and changes in morbidity has been the subject of considerable discussion and speculation (Shapiro, McCormick, and Starfield, 1983). Improvement in both mortality and morbidity are documented, helping to alleviate to some extent the concern that increases in survival may result in a disproportionate increase in handicapping conditions. Dr. Mildred Stahlman draws attention to this concern with the title of her article, "Neonatal Intensive Care: Success or Failure?" (Stahlman, 1984). She responds by stating that any answer has to be qualified, but that spectacular gains have been made.

Having reported on the impact of 30 years of neonatal intensive care on infant outcomes some other observations come to mind. Although we have made much progress in the care of low-birth-weight babies, the fact that we may not be doing so well with large preterm, term, and postterm babies (from both a mortality and morbidity viewpoint) is of concern. One has a much more difficult time finding objective information suggesting that similar great strides have been made in these groups. Providers of comprehensive perinatal care must continue to address mortality and morbidity in the large baby.

At the other end of the weight range, we have the problem of arriving at conceptual and operational definitions of extrauterine viability. This issue has strong emotional overtones. Those who work in neonatal systems know that among professionals there are differences in opinion resulting in judgments in some individual cases. Hess (1953) writes of an "irreducible minimum" due to immature development at birth. That concept probably remains valid, but we need to come to a consensus on definition if we are to use our resources wisely and be fair to our patients.

Another concept and problem that we have attempted to delineate is what we call the "chronic baby." We have arbitrarily defined a chronic baby as an infant who remains under care for longer than 28 days and past their estimated date of birth if they had gone to term, that is, the estimated date of confinement. Although this does not deal specifically with the issue of postponement of neonatal deaths, it is a related area and there is concern that our NICU's are occupied by a significant number of long-term residents.

Once the population of long-term babies is analyzed in this fashion, we find that the length of stay for acute infants, as evaluated by birth weight, has not changed much over the last decade. However, there has been an increase in the length of stay of some babies with birth weights between 500 and 1,250 grams. Babies who are sick and get well in the usual time frame have a length of stay that has remained about the same in the past decade. Those babies who develop long-term complications or pathophysiologic processes are staying longer and longer (Edwards, 1985).

In summary, 30 years of neonatal intensive care has resulted in more survivors and healthier survivors. This period has also demonstrated problems, solutions, new problems, and a resurgence of old problems. The last few years, in particular, have presented more and more public concern and scrutiny, with a special interest in areas such as AIDS, neonatal bioethics, and cost-effectiveness. As a result people in organizations such as the National Institute of Child Health and Human Development, who have been instrumental in the progress of neonatal intensive care over the past 30 years, face many challenges today and tomorrow.

Back to Contents

THE NEONATAL INTENSIVE CARE UNIT TODAY

Dr. Philip Sunshine

The past quarter century has seen tremendous advances in neonatal care. As a result we benefit from a remarkable reduction in neonatal mortality rates, changes in training programs for those who care for at-risk newborns, and the innovative use of our intensive care nurseries for ongoing clinical research.

Reduction in Mortality

Over the past 20 years there has been a marked reduction in the neonatal mortality rates, especially in very-low-birth-weight infants. Twenty years ago we were struggling to enhance the survival of infants weighing between 1,250 and 1,500 grams. Over 90 percent of these infants currently survive the neonatal period. Of infants who weigh between 750 and 1,000 grams, 80 percent will survive, and over 80 percent of the survivors will have few, if any handicaps. These are infants who until a few years ago were considered previable.

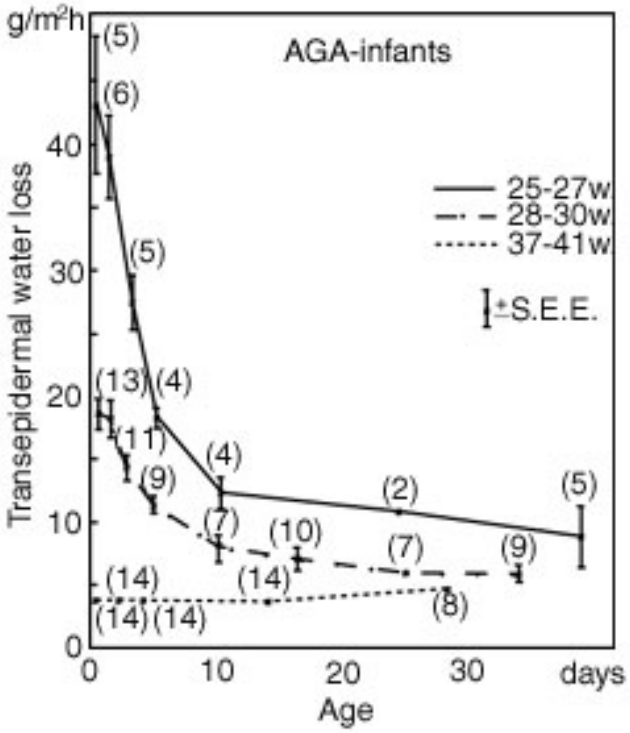
We still face numerous challenges in the care of infants who weigh less than 750 grams at birth. These infants now have a greater than 50 percent mortality rate. Of those that survive, almost 50 percent have some neurological and intellectual handicap (Cohen et al., 1984). Perhaps we are now at the lower end of the spectrum where we can support infants without an artificial placenta or similar technological instrumentation. We obviously still have a long way to go with these infants, but over the years we have had success with gradually decreasing weights and gestational ages.

To what factors do we owe this remarkable reduction in mortality? First, there has been an almost unbelievable development in technology, from the first apnea monitors (Daily, Klaus, and Meyer, 1969) to the equipment now used in most intensive care nurseries. We can provide support and monitoring that had not existed previously. The ventilators we use today to support infants with respiratory insufficiency were developed and designed specifically to respond to the needs of these very tiny infants. The ventilators initially used to support them were primitive and not well adapted to their needs (Thomas et al., 1965).

Newer ventilators (DeLamos et al., 1973), including high-frequency ventilators (Frantz, Stark, and Dorkin, 1980), enable the most immature of infants to be cared for. Monitoring systems and techniques designed to evaluate biochemical and physiological parameters are also used in modern nurseries.

Second, like our predecessors, we recognize that what is appropriate care for the term infant is not necessarily appropriate for the larger preterm infant. What is appropriate for the infant weighing 1,500 grams may not be appropriate care for the infant weighing less than 1,000 grams. It has been found that infants of various gestational ages demonstrate different transepidermal fluid losses (Hammerlund, Sedin, and Stromberg, 1982) (*figure 3*). While fluid restriction in a larger infant is appropriate during the first 12 to 48 hours, these techniques would lead to severe dehydration in the infant who is at 26 weeks of gestation. Similarly techniques to ventilate the larger infant with meconium aspiration syndrome or pulmonary hypertension would lead to disastrous results in the 28-week infant with immature lungs.

Figure 3. *Transepidermal water loss (TEWL) in relation to postnatal age in different gestational age groups. The number of infants is given above each mean value. S.E.E. = standard error of estimate (Hammarlund, Siden, and Stromberg, 1982).* *Permission to reprint by Acta Paediatrica Scandinavica.*



Thus, with improved understanding of the basic physiology and biochemistry of the very-low-birth-weight infant, the use of advanced technology and the development of an aggressive approach to neonatal intensive care, we have dramatically improved the outcome for these immature infants.

Third, is the emergence of nurses who are better educated and increasingly motivated to provide superior care for the neonate. During the early history of NICU's, nurses and physicians alike were learning how to provide this care. However, these experienced and dedicated nurses have developed techniques and approaches to infant care that even the best clinically oriented and motivated neonatologist cannot achieve.

Fourth is the emergence of the fetal advocate, the perinatologist, with whom we share the care of the infant during the last trimester. This continuum of care has significantly lowered the rates of morbidity and mortality. The neonatologist is no longer handed a baby who has been asphyxiated *in utero*, hypovolemic,

and hypotensive. We now have the opportunity to provide intensive care for an infant who is in the best possible condition at birth.

Education

Education has changed considerably in the present intensive care nurseries. At first, people came to the intensive care nursery with varied backgrounds and interests. Many were experts in clinical and basic sciences, although the majority were pulmonologists or cardiologists. They brought their expertise to the care of prematurely born and sick infants and made careful and disciplined observations that led to a better understanding of the biology of the neonate.

We presently operate in a situation that Drs. Gluck and Stahlman warned us about over 15 years ago. Many of us are "training clones or cookie cutters," to coin Stahlman's phrase. We are training physicians who, although experts in providing aggressive and intensive care, may totally lack insight or understanding of the mechanisms of physiology or pathophysiology of the fetus and newborn. Many in the fellowship program are providing intensive care without an opportunity to develop research interests or capabilities in the laboratory that could enhance their academic or clinical careers.

The rigidity of clinical training programs should be abandoned. We must open our fellowships to those who are interested in basic and clinical sciences, and recruit and entice those who would add new and important knowledge on the developing organism. We must make our laboratories and nurseries available to them. We must also realize that neonatologists are often unable to provide the education these individuals require. We may have to seek other investigators in our universities and clinics to provide these fellows with a research foundation they can use to build their own investigative careers. It must be our goal to educate and train postdoctoral fellows who are not only adept clinicians but who will add new scientific knowledge to our current understanding of the newborn.

This is a provocative and difficult challenge. But our approach to the education of fellows must evolve into one of educating clinicians-scientists to assume leading roles in the area of developmental biology and neonatal medicine. We may have to expand the training program to 3 years or even more in order to attain these goals.

The Nursery as a Clinical Laboratory

We must recognize that intensive care nurseries are clinical laboratories and we must recruit and entice investigators to enter our nurseries to carry out innovative studies that will enhance our knowledge. We should look to advisory committees, committees for the protection of human subjects in research, and basic scientists involved in the research of development to help us recruit these scientists.

This is not an easy task. Investigators often prefer to work in the laboratory setting where they can control their experimental models precisely. The study of infants with a multitude of variables is often mind-boggling for the basic investigator. With the rigid controls we have placed upon ourselves through the auspices of the protection of human subjects in research, it is even more difficult to carry out studies in nurseries. A parent who must read a two-page document outlining the study and including every actual or theoretical risk may be reluctant to allow their infant to participate in any study. Rather than abandon investigation, we must learn to perform within these guidelines.

It is essential that nurses and respiratory therapists be recruited into the research arena. These professionals

often make profound and important observations and should be encouraged to devise methodologies to incorporate their observations into meaningful data that others can utilize in clinical care situations.

Innovative therapy and approaches have been introduced when routine care has failed. Many of these maneuvers have resulted in improvement, often of a dramatic nature. These ideas then become part of the routine care of infants in the nursery. Many approaches have never been evaluated scientifically or with appropriate controls, but are adopted as standard care in that particular intensive care nursery.

These programs and facilities must be supported through research, training, and program project grants. Innovative research is costly and with cutbacks in funding, the neonatologist must be an innovative investigator as well as a creative financier. The acquisition of new knowledge and the application of new data are essential to improving the outcome of pregnancy and childhood. As those involved in neonatal intensive care continue in their success, prematurity may become a thing of the past and NICU's relics of a former generation.

Back to Contents

PREVENTING LOW BIRTH WEIGHT AND IMPROVING NEONATAL INTENSIVE CARE: NICHD LOW BIRTH WEIGHT INITIATIVE

Dr. Duane Alexander

The achievements of neonatal intensive care in improving infant survival in the past 30 years are indeed remarkable. However, neonatal intensive care still has its shortcomings. Even though the survival rate is much better, handicaps among survivors remain a major problem. In most cases the isolette is a less satisfactory substitute for the mother's uterine incubator. And neonatal intensive care is expensive, adding billions of dollars in hospital costs to our national health care bill each year.

Even with improved survival, the large number of low-birth-weight infants in this country is the major contributor to our Nation's high infant mortality rate when compared to that of other developed countries.

Eventual Goal

In celebrating the accomplishments of the past 30 years of neonatal intensive care it may seem inappropriate to say that our research goal is to markedly reduce, or do away with, these units altogether by preventing low birth weight. Even the strongest advocates of neonatal intensive care units, however, would fully support that goal. And while none of these units is in imminent danger of closing down in the next few years, that is our ultimate goal.

In pursuing that goal, the NICHD launched a low-birth-weight prevention initiative in 1985. This research effort was designed to attack the twin problems of premature labor and intrauterine growth retardation.

One of the first efforts in this initiative was a cooperative clinical trial jointly supported by the NICHD and the National Institute of Allergy and Infectious Diseases. This trial was designed to test a hypothesis originally proposed by Dr. Louis Gluck, that silent vaginal infections with certain organisms can trigger premature labor because these organisms secrete phospholipase that can cause the release of prostaglandins from the uterus and amnion, and stimulate uterine contractions.

In one of the largest randomized controlled clinical trials ever undertaken by NIH, more than 15,000 pregnant women, at five participating centers, will be screened for the suspect organisms. We will then look at pregnancy outcome in relation to the bacterial culture results. In an intervention arm of the trial, some women with a positive culture are being randomly selected for treatment with an antibiotic or a placebo to see whether eliminating the suspect organisms can reduce the chance of premature labor.

Another NICHD intervention study is taking place in Washington, D.C. The Better Babies Project focuses on areas of Washington, D.C., that have the highest incidence of low birth weight—over 15 percent compared to 6.8 percent nationally. The purpose of this project is to determine whether a community outreach program encouraging pregnant women to receive comprehensive prenatal care early in pregnancy, combined with a wide-ranging effort to reduce their risk for low-birth-weight infants through improved nutrition and weight gain, smoking cessation, and other factors, can reduce the incidence of low birth weight.

Most of the funding for this study is from private foundations, with NICHD providing guidance, study design, and funding for the data collection and analysis. This study is expected to take about 4 years to complete.

For many years the NICHD supported a University of Texas research center focusing on premature labor. In September 1985 the NICHD also awarded new center grants to the University of Cincinnati and the University of Colorado. These centers will try to determine the causes, mechanisms, and possible treatments for intrauterine growth retardation.

New Networks

Until our ability to prevent low birth weight improves, NICU's will continue to be needed, and efforts to improve infant outcomes in these units must be encouraged.

In 1986, the NICHD established two networks—one on neonatal intensive care and the other on maternal-fetal medicine—to apply these new findings in a clinical setting and evaluate their effectiveness and safety in treating sick or premature newborns or women with complications of pregnancy. There are now 12 centers in the Neonatal Intensive Care Network and 11 in the Maternal-Fetal Medicine Network. Ongoing studies include assessing the role of low-dose aspirin in preventing preeclampsia in high-risk patients such as those with diabetes or chronic hypertension, comparing two forms of surfactant used to treat respiratory distress syndrome, and a study of the rate of brain injury associated with intracranial hemorrhage in infants who weigh less than 2 1/2 pounds.

A recently completed project in the Maternal-Fetal Medicine Network was designed to determine whether intravenous gamma globulin administered prophylactically to-low-birth weight babies at high risk for sepsis, a bacterial infection with a high neonatal mortality rate, was effective in cutting the incidence of infection. The study found no difference in the incidence of infection in infants who had received IVIG and those who had not. Many newborn nurseries routinely prescribe IVlG for low-birth- weight infants in an effort to ward off sepsis. The findings from this study will undoubtedly alter that practice, resulting not only in saving dollars now spent on ineffective therapy but more importantly will force attention on developing truly effective means to prevent infection in at-risk newborns.

The NICHD also supports a grant for a research center that focuses on perinatal hypoxia. In addition we support a large number of individual research projects intended to improve our ability to care for the low-birth-weight infant.

With the help of projects and programs like these, enormous progress has been made in improving infant care and survival of premature infants in the 30 years since NICU's were established. The world of pediatrics and neonatology owes an enormous debt of gratitude to Drs. Louis Gluck and Mildred Stahlman for their pioneering efforts, as well as to the many neonatologists who are working to improve neonatal intensive care. Thousands of children and young adults owe their lives to the techniques these physicians have developed.

Much remains to be accomplished, and many investigators working in laboratories and nurseries around the world will continue, over the next 30 years and beyond, to find new ways to reduce the need for neonatal intensive care by preventing prematurity altogether.

Back to Contents

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Back to Top

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