Newborn
Respiratory Care

Marvin D. Lough Thomas J. Williams John E. Rawson

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Edited by

MARVIN D. LOUGH, R.R.T.

Technical Director of Pediatric Respiratory Therapy and Pulmonary Function, Rainbow Babies & Childrens Hospital; Clinical Instructor, School of Respiratory Therapy, Cuyahoga Community College, Cleveland, Ohio

THOMAS J. WILLIAMS, B.S., R.R.T.

Clinical Specialist, Bourns Medical Systems, Inc., Riverside, California

JOHN E. RAWSON, M.D.

Clinical Associate Professor, Department of Pediatrics, University of Mississippi; Chief of Newborn Section, Heines General Hospital, Jackson, Mississippi; Attending Neonatologist, University of Mississippi Hospitals

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*This book is dedicated
to our families, who greatly
supported our efforts:*

KATHY, BRAD, GREG and TODD LOUGH

NANCY and TOM WILLIAMS

MARY, KATHERINE and WIN RAWSON

Contributors

BERNARD BLUMENTHAL, M.D., Assistant Professor of Radiology, University of Mississippi Medical Center, Jackson, Mississippi

STEPHEN J. BOROS, M.D., Assistant Professor, Department of Pediatrics, University of Minnesota; Director of Newborn Medicine, St. Paul Children's Hospital, St. Paul, Minnesota

JANE H. DAVIS, A.S.S.S., A.C.S.W., Department of Social Work Services, Kennedy Memorial Hospital for Children, Boston, Massachusetts

DONNA DEMONTERICE, R.N., M.N., Nurse Clinician, Neonatology; Assistant Clinical Professor of Pediatric Nursing, Case Western Reserve University and Rainbow Babies & Childrens Hospital, Cleveland, Ohio

MICHAEL GALGOCZY, M.S., C.R.T.T., Pediatric Respiratory Therapy, Rainbow Babies & Childrens Hospital, Cleveland, Ohio

ROSANNE GUGINO-TOUFEXIS, R.N., M.S., Regional Education Coordinator, Cleveland Regional Perinatal Network, Cleveland, Ohio

MARVIN D. LOUGH, R.R.T., Technical Director of Pediatric Respiratory Therapy and Pulmonary Function, Rainbow Babies & Childrens Hospital; Clinical Instructor, School of Respiratory Therapy, Cuyahoga Community College, Cleveland, Ohio

GERARD W. OSTHEIMER, M.D., Assistant Professor of Anaesthesia, Harvard Medical School, Anesthesiologist, Boston Hospital for Women, Boston, Massachusetts

BRUCE R. PARKS, JR., PH.D., Assistant Professor of Pediatrics; Instructor in Pharmacology, University of Mississippi Medical Center, Jackson, Mississippi

JOHN E. RAWSON, M.D., Clinical Associate Professor, Department of Pediatrics, University of Mississippi; Chief of Newborn Section, Heines General Hospital, Jackson, Mississippi; Attending Neonatologist, University of Mississippi Hospitals

BRADFORD RICHMOND, M.S., C.R.T.T., Pediatric Respiratory Therapy, Rainbow Babies & Childrens Hospital, Cleveland, Ohio

BARBARA SCHUCHARDT, R.R.T., Pediatric Respiratory Therapy, Rainbow Babies & Childrens Hospital, Cleveland, Ohio

THOMAS J. WILLIAMS, B.S., R.R.T., Clinical Specialist, Bourns Medical Systems, Inc., Riverside, California

Preface

THIS BOOK was conceived as part of an effort to assist students and postgraduate health personnel, including respiratory therapists, nurses and physicians interested in the care of ill newborn infants. The text represents a compilation of the experience of many dedicated individuals with a primary concern for the health care of the newborn infant. In the past decade, the field of neonatology has grown tremendously and texts have been published that deal with the over-all care of the newborn infant. We will not attempt to duplicate the already-existing texts but instead place greater emphasis on newborn respiratory care at the clinical level. Attempts have been made to provide a learning venture from the time of conception through the newborn period. The information provided on the development of the cardiorespiratory system as related to health and disease has been brought together in a concise and useful manner. Methodology and techniques for newborn respiratory care have been provided from the time of delivery through the intensive care period. Since continuous positive airway pressure and mechanical ventilation play such an important role in newborn respiratory care, we have devoted separate chapters to each. The section dealing with disease is oriented to a description of those problems requiring respiratory care. Radiologic findings and effects of drugs are detailed as they relate to infants. The nursing chapter provides comprehensive coverage of those nursing procedures that are related to pulmonary care. The chapter on care of the parents details the psychologic problems associated with having an ill infant.

The information provided in this text is based on the broad experience of many health care professions. It is clear that the perinatal mortality rate over the past 25 years has declined but its associated problems are far from solved. It is our hope that the knowledge and experience detailed in this text will help to improve the morbidity so that the surviving infants can lead productive lives.

We wish to acknowledge the invaluable assistance of Barbara Schiffhauer, who typed the manuscript, and Angel Martinez for his help with the illustrations.

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MARVIN D. LOUGH
THOMAS J. WILLIAMS
JOHN E. RAWSON

Introduction

> "Everything ought to be done to ensure that an infant be born at term, well-developed, and in a healthy condition. But in spite of every care, infants are born prematurely . . . ." —PIERRE BUDIN, *The Nursling*, 1907

OUR CHILDREN are our future. The care of children has always been a major activity of mankind. The modern era in special care for premature infants began in Paris, in 1892, when Dr. Pierre Budin became interested in the congenitally feeble and weakling infant. He opened his consultation service for nurslings at the Charity Hospital in that year and published his book *The Nursling* in 1907. Martin Cooney, one of Doctor Budin's students, recognized the public's interest in prematurely born infants and established exhibits to which he charged admission. One of his first exhibits was at the Chicago Exposition in 1914.

The shift of childbirth from the home, with lay-trained assistants, to the hospital, with well-trained health specialists, has made birth a medical rather than a family-centered event. Before the antibiotic era of the 1940s, hospitals enforced stringent controls on the patient, health care personnel and visitors to the maternity area in hopes of preventing the spread of infection. This resulted in the "hands off" concept, the practice of isolating the infant from its parents and the total exclusion of visitors, for sterility's sake alone. The safeguards provided by a hospital environment were soon accepted, and the popularity of hospital births soared.

The establishment of neonatal intensive care units, in the late 1960s, has been one of the most significant contributions toward reduction of perinatal mortality. One of the most common problems in the neonatal intensive care unit today, and the major cause of mortality, occurring in 0.5–1.0% of all deliveries, is hyaline membrane disease. This disease is characterized by increased work of respiration and cyanosis. Most of the early research was empirical and designed to decrease cyanosis and improve ventilation. Not all of these efforts have been without risk. The use of oxygen had a beneficial effect but was later shown to contribute to retrolental fibroplasia and blindness. When this association was recognized, it led to a severe curtailment in the use of oxygen. The result was a reduction in the incidence of retrolental fibroplasia and blindness but an increase in the number of premature infants who were neurologically damaged. Although the use of oxygen has been the most publicized problem associated with serious complications in the search for ways of improving the outcome of premature infants, many of the new techniques have introduced new complications or diseases.

Mechanical ventilation of newborns was first introduced as a resuscitative technique in the delivery room for infants who failed to quickly establish normal respiration. The earlier devices were crude and suitable only for short-term use. In the 1960s, infants were placed on scaled-down negative-pressure ventilators or adult positive-pressure ventilators modified for the newborn. In the 1970s, newborn ventilation gradually became an acceptable medical practice outside the research institution. This was possibly because of the development of reliable neonatal ventilators and the availability of equipment for microsample blood gas analysis. The technologic advances in mechanical ventilation, patient monitoring and laboratory support equipment have provided the tools for respiratory care of newborn infants.

The requirements for an effective neonatal intensive care unit are so stringent in terms of clinical equipment, laboratory equipment, space and trained personnel that only a select few hospitals can meet the financial obligation. To deal with this problem, a national policy on regionalization of perinatal care has been developed by the American Medical Association, the American College of Obstetrics and Gynecology, the American Academy of Pediatrics and the American Academy of Family Physicians. These sponsoring organizations recommended that the nation be divided into regions with 12,000–14,000 deliveries per year. Hospitals in each region are to be divided into 3 classes; in each area there would be one institution that would accept the responsibility for coordinating perinatal health care activities. This would include providing specialized facilities for high-risk obstetric and newborn patients, organizing referral and transporting systems in other regions and coordinating both public and professional education for perinatal care in their region.

The federal government has recognized this concept as policy and has classified hospitals in the following manner: Level 1 (primary care) hospitals will provide service primarily for uncomplicated maternal and neonatal patients. These units exist primarily because of geographic or cultural situations that limit access to units with greater care and capabilities. Level 2 (secondary care) facilities are those hospitals that have larger maternity and newborn services. In addition to providing a full range of maternal and newborn services for perinatal patients who have no complications, they will also provide services for some more complicated obstetric and neonatal problems that fall within their capabilities. These capabilities will depend on the resources available. Level 3 (tertiary care) facilities, in addition to the resources and capabilities of a Level 2 unit, are able to provide a full range of services for all serious maternal illnesses and newborn intensive care. Established arrangements should be provided for early access of high-risk pregnant women and prompt referral among levels of care as appropriate.

The initial efforts of implementing this plan have required local adaptation to special needs in each location. The requirement of maintaining 1500 deliveries per year to be classified as a Level 2 center has posed problems in many states with low populations. Each state now has a health service area council and/or state health planning council with the authority to issue a "certificate of need" for all new services. The guidelines set forth by these councils are serving as the basis for decisions on the need for new perinatal services.

Perinatal health care is rapidly changing with the advent of new technologies, new approaches to patients, new funding mechanisms and the organization of new services. The successful delivery of high-quality care to perinatal patients requires not only excellence from physicians, therapists, nurses and other health professionals as individuals but also a mechanism or system of organization that permits them to function as a cohesive and well-coordinated team. This book focuses primarily on the respiratory complications of the newborn infant and discusses medical, technical and social issues related to the care delivered by this invaluable team.

JOHN E. RAWSON

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BRADFORD RICHMOND, M.S., C.R.T.T.
AND
MICHAEL GALGOCZY, M.S., C.R.T.T.

AN UNDERSTANDING of the developmental aspects of the cardiovascular and respiratory systems is crucial to the proper management of postpartum complications that occur in infants involving these organ systems. The selection of supportive modes of therapy, as well as the type of equipment used, may be dependent on the gestational age of the fetus. This point is especially important when considering cardiorespiratory support. The lungs require a greater amount of time to develop sufficiently to support life than does the cardiovascular system. Knowledge of the embryologic origins of the heart is essential in order to understand the various abnormalities that are associated with this organ system. Knowledge of fetal circulation and the transition of circulation that occurs pre- to postpartum is important to facilitate treatment of an infant in distress. Comprehension of newborn developmental aspects of the unborn infant may be fully appreciated only after clinical exposure to a newborn suffering from a respiratory and/or cardiac problem.

INTRODUCTORY CONCEPTS

Like all multicellular species, humans have a limited life span and thus require some mechanism to perpetuate and produce successive generations of their species. This mechanism is called reproduction, which is effected by a complicated process that requires the presence of two sexes, male and female, each of which contributes specialized sex cells called gametes. The organs that produce the gametes are known as the gonads, or primary sex organs. Gonads of the male are the testes, which produce gametes called spermatozoa or sperm. The female gonads are the ovaries, which produce ova or eggs.

The gametes are produced by their respective gonads through a series of mitotic (mitosis) and meiotic (meiosis) events that occur in gametogenesis or the formation and maturation of germ cells. In the male this process is referred to as spermatogenesis, and in females it is called oogenesis. Mitosis is the process of cell division in which each chromosome, that is, the hereditary material composed of strands of deoxyribonucleic acid (DNA) responsible for an individual's genetic make-up, is duplicated and passed on to daughter cells. Thus, mitosis is extremely important in higher forms of life. It ensures that each daughter cell will be genetically alike to its parent cell and, therefore, compatible with every other cell in the individual's body. Mitosis occurs primarily in the somite or body cells. Meiosis is the specialized form of cell division that seems to occur only in the germ cells (i.e., gametes), resulting in the formation of daughter cells that contain a haploid number of chromosomes. The haploid number of chromosomes is one-half the normal complement of chromosomes that normally are present in an organism. In humans, the haploid number is 23 as opposed to the diploid number of chromosomes, 46, that results from mitosis of the somatic cells.

In addition to the primary sex organs, each sex usually is characterized by the presence of accessory sex organs or secondary sex characteristics. These are required to transmit the gametes that have been generated by the gonads. In the male, the accessory sex organs include the penis, which enables the sperm cells to be deposited in the female genital tract. The accessory sex organs in the female include the vagina, which is a special receptacle for the sperm cells, and the uterus, for reception and incubation of the zygote, which will be discussed below.

Development of an organism begins with fertilization. A sperm unites with an oocyte (egg) to form a zygote (from the Greek *zygōtos*, meaning "yoked"), which requires approximately 24 hours. Fertilization (stage 1 of development) of the ovum occurs in the ampulla portion of the oviduct. An ovum contains a half set of 23 chromosomes with a nutrient supply (the yolk), which is required for the initial developmental activity. The fertilizing sperm donates the other 23 chromosomes for a complete set of genes. In general, only one sperm cell penetrates the ovum. Figure 1–1 illustrates the penetration of the oocyte by the sperm and the procession of events that lead to the formation of the zygote once penetration has occurred. The sex of the embryo is determined at the time of fertilization by the kind of sperm that fertilizes the oocyte. Human cells contain 46 chromosomes; 22 pairs of these chromosomes are somatic, whereas the twenty-third pair

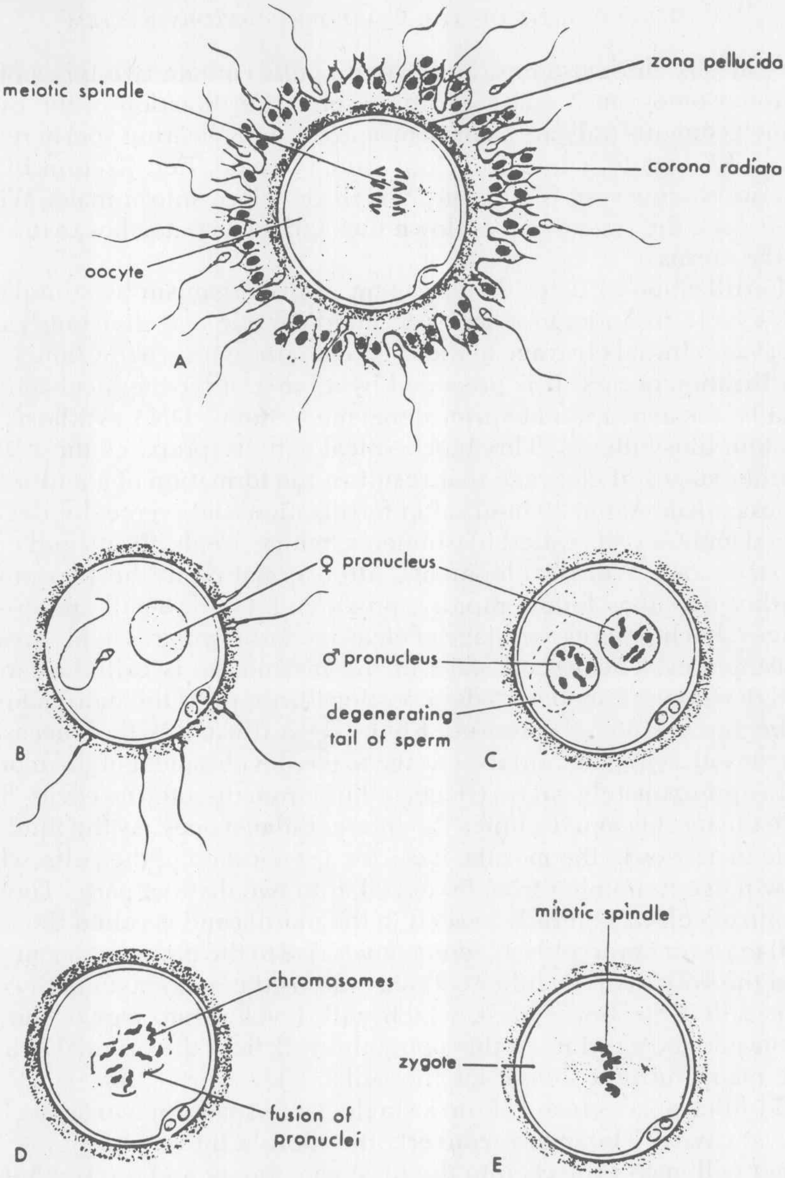

Fig. 1–1. – Fertilization, the process of sperm and egg uniting to establish a full complement of chromosomes (46) forming a zygote (not all chromosomes are shown). **A,** secondary oocyte about to be fertilized; **B,** sperm entered oocyte; **C,** male pronucleus forms containing chromosomes of sperm; **D,** pronuclei of male and female fuse; **E,** zygote with full chromosome complement is formed. (From Moore, K. L.: *The Developing Human* [2d ed.; Philadelphia: W. B. Saunders Company, 1977]. Reprinted by permission.)

are the sex chromosomes. Male sperm cells contain two types of sex chromosomes: an X and a Y chromosome. Fertilization of the ovum, which contains only an X chromosome, by an X-bearing sperm results in an XX zygote, which develops into a female. Fertilization by a Y sperm produces an XY zygote, which develops into a male. Within 3–5 days, the zygote moves down the oviduct and attaches to the wall of the uterus.

Fertilization initiates development of the organism by stimulating the zygote to undergo a series of rapid mitotic cell divisions called cleavage. Initial cleavage of the zygote begins within a few hours after fertilization occurs. It is preceded by a burst of biochemical activity; that is, the activation of various enzyme systems, DNA synthesis and protein biosynthesis. This biochemical activity prepares the cell for further stages of cleavage that result in the formation of a multicellular organism. About 30 hours after fertilization, the zygote divides into two daughter cells called blastomeres, which are duplicate and equal in size (stage 2 of development). After formation of the blastomere, further divisions follow rapidly, producing 4-cell, 8-cell and 16-cell stages. Each progressive stage of cleavage forms progressively smaller blastomeres. The 16-cell stage of the blastomere is called a morula and develops after about 3 days postfertilization. As the morula forms, it begins to enter the uterus. Figure 1–2 illustrates the successive stages following the initial cleavage to the development of the morula.

In approximately 4 days (stage 3), fluid from the uterine cavity flows into the morula and occupies the intercellular spaces. As the fluid volume increases in the morula, it causes a separation of the cells, which now range in number from 50 to 200, into two distinct parts. The first group of cells is centrally located in the morula and is called the inner cell mass (or embryoblast), which gives rise to the embryo, the amnion and the yolk sac. The other cell mass forms the outer layer of the morula, called the trophoblast, which will develop into part of the placenta and the chorion. At this point, the yolk from the original ovum is the main nutrient source for the cells. After a brief time lapse, the fluid-filled spaces fuse to form a single, large space known as the blastocyst cavity. This phase converts the morula into a blastocyst. The inner cell mass projects into the blastocyst cavity and the trophoblast forms the wall of the blastocyst. The blastocyst lies free in the uterine secretions for approximately 2 days, then the zona pellucida (the noncellular, secreted layer surrounding the ovum) degenerates and disappears, heralding the start of the implantation stage (Fig. 1–3).

In order for further development of the embryo to occur, implantation of the blastocyst in the uterine wall is essential. During the fifth