Chapter 4
Neonatal Care and Data

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Objectives

- To characterize baseline information about pregnancy, labor, and delivery needed by neonatal practitioners during birth and transition from obstetrical to pediatric care
- To outline medical concerns of premature infants, the levels and environments of neonatal care and the information needs in the transition from neonatal to primary care
- To describe information challenges in neonatal care

4.1 Introduction

Neonatology encompasses the care of all infants: from term newborns to extremely premature infants, from healthy infants to those suffering from severe infections or genetic disorders. While the management of infants can vary greatly, there are essential core data and knowledge that is needed to care for them.

4.2 The Mother–Infant Dyad

In neonatal care, the medical history covers two patients: the mother and the infant. Thorough knowledge of the maternal history (medical, obstetrical, medication, and social) is crucial for evaluating any newborn. The efficient and accurate transfer of this information from the obstetrical to neonatal providers is a great challenge, but can benefit care tremendously.

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4.2.1 Maternal Medical and Obstetrical History

Essential maternal medical and obstetrical information includes:

Maternal Age—Pregnancies in women who are young (teenage) or older than 35 years of age are at risk for complications. Risks that younger pregnant women face include preeclampsia, sexually transmitted diseases, lack of family and financial resources and others.[1–3] Problems faced by older pregnant women include increased risks for eclampsia, needs for caesarean delivery, diabetes, and abruption, as well as increased probabilities of genetic abnormalities in offspring.[4]

Maternal Past Medical History—The developing fetus is an integral part of the mother, and systemic maternal conditions, such as diabetes, hypertension, and diseases such as systemic lupus erythematosis or hyperthyroidism can have profound effects on its growth. Knowledge of the severity and etiology of maternal conditions and relevant maternal data near delivery is important for newborn care. For example, mild maternal gestational diabetes mellitus can evoke fetal secretion of insulin leading to macrosomia and neonatal hypoglycemia shortly postdelivery, while severe diabetes of long standing may compromise fetal growth due the negative effects on the placenta from vascular disease.[5] Some neonatal conditions influenced by maternal medical conditions may not be evident until well after hospital discharge. Continuity between the maternal record and the ongoing infant record is important to the primary care pediatrician.

Prior Pregnancies and Neonatal Illnesses—Conditions from prior pregnancies also often present in subsequent pregnancies. For example, Group B Streptococcal (GBS) disease in one newborn also places subsequent newborns at risk for this infection.[6] Examples abound and any obstetrical/neonatal information tracking system must allow for flexible and thorough documentation of prior pregnancies.

Family History—The family history is an important component of any medical evaluation. While adult diseases (coronary artery disease, adult onset cancer, etc.) often contribute little to newborn care, extended families may have histories of unexplained childhood deaths or illnesses that can raise suspicion for potential illness (metabolic, structural, respiratory, etc.) in the newborn.

4.2.2 History of the Current Pregnancy

Detailed knowledge of the current pregnancy is vital, but may be difficult to obtain, particularly when complications prompt emergency delivery. Prenatal obstetrical care is largely delivered in outpatient centers that are associated to labor and delivery wards of delivering hospitals. A major impediment to the development of complete electronic patient records has been the inherent difficulty of integrating timely outpatient data into inpatient records, particularly during nonbusiness hours (nights, weekends, and holidays).

Essential prenatal information includes:

Gestational Age—An infant may be term (between 37 and 42 weeks gestation), preterm (<37 weeks) or postterm (>42 weeks),[7] where weeks are counted from the date of the last menstrual period (LMP), sometimes called post-menstrual age (PMA). The date of (term) delivery (also called the "estimated date of confinement" or EDC) can be calculated from the gestational age, when known or estimated from physical exam. Obstetricians may modify the estimated due date based on ultrasound, if the mother's LMP is unknown. The gestational age (in days) of fetuses conceived via assisted reproduction (ART) is determined by adding 14 to the number of days since implantation of the fertilized egg.[8]

Number of Expected Fetuses—Until recently, higher ordered multiple gestations (triplets, quadruplets, etc.) were rare. Assisted reproduction has made twins and triplets commonplace. Between 1980 and 1997, the number of twin live births rose 52% and the number of triplets and higher order deliveries rose 404%.[9] Higher-order pregnancies are at higher risk for complications and prematurity is commonplace.

Prenatal Studies—Prenatal care usually includes a standard battery of prenatal laboratory tests at various points during pregnancy. Some tests (screens for maternal HIV, group B streptococcal and drugs of abuse) may prompt treatment protocols for mother and infant. These test results are a vital part of the prenatal and infant record and must be easily available as they can influence care shortly after birth.

Prenatal laboratory test results include:

- Maternal blood type and Rh (Rhesus antigen)
- Maternal antibodies against known blood antigens
- Group B Streptococcal (GBS) screen
- Maternal antibodies for syphilis—VDRL or RPR
- Presence of Hepatitis B surface antigen and antibody
- Maternal immunity to toxoplasma, rubella, cytomegalovirus, and herpes
- Maternal tests for HIV, gonorrhea, and chlamydia (often sent at obstetrician's discretion)
- Maternal toxicology screen

Each of these results has implications for evaluation and treatment of the newborn, such as the administration of Hepatitis B immune globulin in addition to Hepatitis B vaccine.[10]

A major challenge of neonatal care is collection and processing of maternal data from obstetric records when outpatient offices are closed. In some cases, this may leads to duplication of maternal testing and possible unnecessary treatments of the infant. Linkage of information between hospitals and obstetric offices could decrease this problem. In some cases, maternal prenatal lab tests processed at the intended delivery hospital can facilitate data availability at delivery.

Pregnancy Complications—The evolution of a pregnancy greatly impacts neonatal conditions. Potential complications include premature labor, fetal growth

restriction, pregnancy-induced hypertension, pre-eclampsia, and others. These complications can extend maternal hospitalization, sometimes for weeks, well before delivery.

Fetal Ultrasounds/Echocardiograms—Prenatal ultrasound provides an opportunity to estimate gestational age and identify problems in the developing fetus. A suspected heart malformation prompts a fetal echocardiogram and cardiology evaluation. An ultrasound-detected heart or other malformation may critically determine the location of delivery, the resuscitation protocol and treatment plan shortly after birth.

Maternal Infections During Pregnancy—Infections by viruses, bacteria, and fungi may affect the developing fetus and newborn. Some infections, particularly viral infections, may cross the placenta and have severe, sometimes fatal effects. Other maternal infections, such as urinary tract infections, place the infant at higher risk for bacterial infections after birth. Others, such as TORCH infections, may place the infant at risk for life-long complications. The prenatal course and treatment of maternal infection may help determine the extent of evaluation and need for treatment of the newborn.

Pregnancy Interventions—Perinatologists and surgeons are increasingly able to directly intervene in the course of fetal development. Some of these interventions have been well accepted (amniotic fluid sampling, fetal transfusions), while others (fetal surgery) are experimental. Nevertheless, fetal interventions will likely become more frequent in the future and their incorporation into a maternal–fetal record electronic record should be standard.

Consulting Physicians—Pediatric subspecialists (geneticists, nephrologists, cardiologist, neonatologists, and others) may meet with expecting parents prior to delivery and may participate in postnatal care. Easy access to information about specialists' involvement and their contact information may help to streamline infant care after delivery.

4.2.3 Labor and Delivery

Delivery records must document the onset of labor, time of rupture of membranes, presence of maternal fever, type and timing of medications/anesthesia administered to mother and method of delivery (vaginal, Caesarean, forceps, or vacuum). Obstetricians often note the presence of fetal heart rate decelerations prior to delivery that comprise four varieties: early, late, variable, and prolonged. While documentation may indicate only the presence of "decels," the type, frequency, duration, and severity of fetal heart rate deceleration may indicate placental insufficiency.[7] Meconium may be passed in utero and its presence in amniotic fluid place the infant at risk for fetal meconium aspiration and respiratory distress after birth. Additionally, infection of the amniotic fluid, chorioamnionitis, may produce malodorous, cloudy amniotic fluid and place the newborn at high risk for bacterial infection.

4.3 The Infant

4.3.1 Neonatal Resuscitation

As a part of delivery, the newborn's condition is immediately assessed. Many infants are initially cyanotic with rapid improvement as breathing begins. Some infants require resuscitation, which may be complex and prolonged, for a variety of reasons, including persistent apnea, prolonged cyanosis, bradycardia, or poor tone. The APGAR score is assigned to describe the infant's initial condition and response to resuscitation (Table 4.1).[11] Good documentation of resuscitation describes an infant's condition, resuscitation steps instituted and response to resuscitation. Because resuscitation may be prolonged and time is often short, thorough documentation may be difficult and may follow resuscitation and stabilization of the infant. While real-time documentation of resuscitation would be ideal, manpower and space for a human scribe are often limited in the delivery or operating room.

4.3.2 Is It a Boy or a Girl?—The Special Cases of Ambiguous Genitalia

While many parents learn the gender of the newborn during an antenatal ultrasound, some prefer wait to know until delivery. In most cases, the gender is readily apparent, but in a small percentage of newborns, the gender is not immediately evident in the delivery room and assignment must be deferred. Ambiguous genitalia require careful discussions between all members of the treatment team and parents.[12] As such, premature assignment of gender is inappropriate.

4.3.3 How Big Is the Baby?

The birthweight, length, and head circumference determine whether an infant is appropriately sized for the estimated gestational age based on normative values readily available on growth charts. Infants who are smaller than expected (<10%) are *small for gestational age* (SGA) while infants who are larger than

Table 4.1 The APGAR score

Score parameter	0	1	2
Color	Cyanotic or pale	Acrocyanosis	Pink
Pulse	0 (Asystolic)	<100/min	>100/min
Reflex irritability	None	Grimace	Cries
Tone	Flaccid	Decreased	Active motion
Respirations	Apneic/gasping	Irregular	Good
Total			

expected (>90%) are *large for gestational age* (LGA).[13] Those infants whose weight, head circumference, and length are between the 10th to 19th percentiles are *appropriate for gestational age* (AGA). While parents in United States almost exclusively use the English system (pounds, ounces, inches) when referring to the weight and length of the newborn, medical care of newborns, particularly medication dosing, requires these measurements in metric.

4.4 Well Baby Care

4.4.1 The Newborn Nursery

In many cases, term newborns stay in the mother's room to facilitate bonding and feeding or are admitted to a well baby nursery, with anticipated discharge in 48–72 h. Routine newborn care is often high-volume and information systems that link obstetrical care to newborn nursery to primary pediatric care may bring benefits in multidisciplinary care and patient satisfaction.[14]

4.4.1.1 Challenges of the Newborn Nursery

In a typical community nursery, primary care practitioners (pediatricians and family practitioners) examine infants and review their records in the morning prior to seeing patients in the outpatient setting. Challenges include:

Identifying Subtle Signs of Illness—Early signs of illness in the newborn may be subtle. Some, such as difficulty in establishing feedings after delivery or heart murmurs may not manifest until after discharge, yet can be life-threatening if not detected early.

High Patient Volume—Newborn nurseries vary greatly in size. Larger nurseries may employ hospitalists in addition to private pediatricians and family physicians to examine newborns prior to discharge. A challenge to planning newborn nursery information systems is the collection of examination data for documentation and conveyance to primary care practices efficiently, particularly when patient loads are high.

Critical Laboratory Values—Efficient and coordinated notification of abnormal laboratory test results, such as direct antibody tests (DAT), complete blood counts (CBCs), electrolytes, blood glucoses, and blood gas determinations may alert nursery physicians to potentials for problems that may delay discharge or require further workup or referral to a neonatal intensive care unit.

Identification of Infants Who Will Require Close Follow-Up—Most infants are discharged from the nursery by 48 h of age with office follow-up at 1 week, but

some may be eligible to go home with closer follow-up. Issues such as resolving jaundice, early discharge from the hospital and first-time breast feeding mothers may require a coordinated follow-up visit sooner than 1–2 weeks. Continuity of care from the nursery to primary care can be enhanced by phone calls to follow-up physicians, in addition to hospital documentation. The typical summary for term newborns contains:

- Maternal medical and obstetrical history, including maternal medications
- Labor and delivery history, including prenatal test results (Group B Strep status, RPR, Rubella, HIV, maternal blood type, maternal gonorrhea, and chlamydia results)
- A summary of the neonate's course, including resuscitation and Apgar scores, physical exam, birth and discharge weights, laboratory values (bilirubin levels, infant/mother blood types, DAT, CBC), stooling/voiding patterns, administration of hepatitis B vaccine, and infant feeding.

Newborn Screening—Newborn screening test results are usually unavailable at the time an infant is discharge, and require follow-up with the primary care practitioner. These screens include:

- Metabolic testing (which varies from state to state)[15]
- Newborn hearing screen[16]
- Specific tests for infants at risk (genetic testing, intrauterine infection screens (TORCH[17]))

4.4.1.2 Ill Term Infants at a Community Hospital

Although many hospitals provide low level neonatal intensive care, very ill term infants requiring mechanical ventilation and advance life support must be stabilized and transported to the closest neonatal intensive care unit (NICU)[18]. Term nursery planning includes standardized procedures for the management and transfer of such infants, including:

- Medical stabilization protocols for infants (including appropriate equipment and trained physicians)
- Coordination and transport of infants to known NICUs
- Information transfer and documentation of care

Well-designed information systems within a regional network can facilitate the gathering of needed information. Transfer documentation for neonatal transport includes: a summary by the clinician of the infant's course and copies of the nursing flow sheets, medication records, laboratory results, and radiographic studies. Design of computerized systems, in addition to collecting and making necessary information available, should facilitate its summarization and organization for optimal care.

4.5 Neonatal Intensive Care

Premature births currently account for 10–12.5% of all births in the United States.[19,20] Advances have extended survival of infants as early as 23 weeks gestation, with standard treatments for previously fatal diseases such as respiratory distress syndrome (RDS).

4.5.1 NICU Environments

Neonatal nurseries comprise a range of facilities of different sizes and capabilities. The March of Dimes reports "Toward Improving the Outcome of Pregnancy" (TIOP I and TIOP II) described criteria stratifying nurseries according to the complexity of care.[18, 21,22] Level I nurseries offer basic resuscitation and care for uncomplicated deliveries. Level II (specialty) nurseries offer care for limited conditions that are expected to resolve quickly and that do not require extensive care. Level III (subspecialty) nurseries offer complex care, including surgical interventions, for critically ill term and preterm infants. Further classification, that addresses the need for regionalization of specialized critical care, such as extracorporeal membrane oxygenation (ECMO) and neonatal cardiac surgery, has been proposed.[23] Higher level NICUs employ high-risk obstetricians, perinatologists, neonatalogists, pediatric subspecialists, and neonatal nurses, dieticians, pharmacists, and respiratory therapists.

4.5.2 Crucial Issues of Prematurity

Prematurity is defined as birth occurring at less than 37 completed weeks since the onset of the LMP. The range of gestational ages of premature infants conveys a range of birth weights (that may extend to as low as 400–500 g) and risks for both morbidity and mortality. Viability indicates the possibility, but not the probability of long term survival. The limit of viability varies but may be estimated to be 23–25 weeks. Because of their premature systems, these infants are at risk for a number of problems.

4.5.2.1 Pulmonary Immaturity

Respiratory insufficiency or failure is a frequent consequence of prematurity and may be multifactorial in nature. Premature infants are at risk for *respiratory distress syndrome* (RDS), due to surfactant deficiency and structural lung immaturity. Therapies to support infants with immature lungs include endotracheal administration of surfactant and ventilatory support. Premature infants with RDS are at risk for subsequent chronic lung disease (*bronchopulmonary dysplasia*).[24]

Measures of respiratory distress include: vital signs (respiratory rate, heart rate, and oxygen saturation), the physical exam and arterial blood gas results (pH, PaO_2, $PaCO_2$) and physiologic measures such as mean airway pressure (MAP) and inspired oxygen (FiO_2), with the Oxygenation Index (OI)[25] as a calculated measure whose trends can be tracked over time.

$$OI = (MAP \times FiO_2 \times 100)/PaO_2$$

Infants with relatively mild respiratory insufficiency may be placed on one of several varieties of continuous positive airway pressure (CPAP, a device that blows air into the nose at a controlled pressure): bubble CPAP, mask CPAP, and prong CPAP. CPAP pressure must be tracked as it follows potential improvement or worsening of respiratory status. Infants who experience failure with CPAP require mechanical ventilation.

Mechanical ventilation of the premature neonate is a complex and controversial topic. Two general varieties of mechanical ventilation are available: *conventional ventilation* and *high frequency ventilation*. Conventional ventilation provides a standard breath (pressure or volume) into the lungs at a given minimum rate per minute, dependent on the ventilator settings. Available neonatal systems incorporate these varieties and offer the user the ability to adjust variables (tidal volume, peak pressure, rate, PEEP, and others). The second major classification of ventilators is the high-frequency ventilator. Several types of these ventilators are available.[26] High frequency ventilation provides small gas volumes at rapid rates to decrease the pulmonary trauma. The most common type is *high-frequency oscillatory ventilator* (HFOV or oscillator) which cycles air in and out of the lungs rapidly. The oscillator has relatively few variables to track: mean airway pressure (MAP), displacement (delta P), frequency, and FIO_2. While the individual level of these variables is very important, the trends of the variables and blood gas results provide a highly useful picture of an infant's respiratory status. Two other types of high frequency ventilators are in general use include the *jet ventilator*, which is similar to the oscillator, but cumulatively provides for oxygenation and removal of waste gases and *high frequency flow interrupters (HFFI)*. The jet ventilator is used in combination with a conventional ventilator to provide positive end-expiratory pressure (PEEP) and intermittent breaths. It is more complex than a conventional ventilator, with different variables: jet peak pressure (JPIP), inspiratory time, back up PEEP (baseline pressure), back up rate (0 to several breaths per minute) and back up peak pressure. HFFI is similar to jet ventilation but uses slower rates.[27]

Airway pressure release ventilators (APRV) have also been used on neonates, but on a more limited basis.[28]

4.5.2.2 Cardiovascular Instability

The tremendous cardiovascular changes occur during the transition from intrauterine to extrauterine life place premature infants are at high risk for two particular

cardiovascular problems: patent ductus arteriosus (PDA) and hypotension. PDA is a persistence of an essential fetal connection (the ductus arteriosus) between the pulmonary artery and aorta that normally closes within 12–24 h in term neonates. In premature infants, the PDA can worsen respiratory distress and lower systemic blood pressure. Various medical and surgical therapies are used to close the duct.[29]

Hypotension, another complication of prematurity, is a poorly defined entity in extremely preterm infants. At this time, neonatalogists commonly attempt to keep the mean blood pressure at least the gestational age during the first several days after birth.[30]

$$\text{Mean blood pressure} = \text{DBP} + 1/3 * (\text{SBP} - \text{DBP})$$[31]

The medical management of hypotension includes:

Continuous intravenous infusions of vasopressors (dopamine, dobutamine, epinephrine) are administered on a *microgram per kilogram per minute* rate (unlike narcotics, which are infused on *a microgram per kilogram per hour* rate). Manual calculation of infusion rates and doses is error-prone. Errors can be reduced through the design and mandated use of calculators[32] that can be used in stressful situations. In addition to calculators, the mandated use of standard concentrations for continuous infusion medications[33] by the Joint Commission, which limits available concentrations of medications, thus reducing pharmacy preparation errors. The large variations in neonatal weights may create fluid overload for premature infants, but this may be offset by the use of computerized "smart" pumps (See Chapter 28).

Steroids (in particular hydrocortisone), dosed by weight (mg/kg/day) or by body surface area (BSA) may help stabilize blood pressure (using calculator support):

$$\text{Neonatal Estimated BSA } (m^2) = 0.05 \times \text{Wt (Kg)} + 0.05$$

4.5.2.3 Neurologic Immaturity and Vulnerability

Extremely premature infants are at risk for brain damage due to hypoxic and ischemic insults to the developing brain and nervous system. Infants less than 34 weeks gestational age (at birth) are at significant risk for *intraventricular hemorrhage* (IVH).[23] Hemorrhages, detected using cranial ultrasonography, can range from very small to catastrophic, lethal hemorrhagic infarctions,[34] which may create *posthemorrhagic hydrocephalus*, requiring neurosurgical intervention. *Periventricular leukomalacia* (PVL), resulting from blood flow instability and exposure to infection among extremely premature infants, may be detected by cranial ultrasound and places an infant at significant risk for long term developmental problems. The presence of intraventricular hemorrhages, periventricular leukomalacia, or hydrocephalus is vitally important for future medical and developmental care and this information must be clearly conveyed to future physicians and allied developmental professionals.

4.5.2.4 Susceptibility to Infection

Premature infants are immunologically naïve and vulnerable to a number of serious systemic infections, not only from maternal sources, but also those associated with hospitalization: vascular catheters, ventilator associated pneumonias, and necrotizing enterocolitis.[35]

4.5.2.5 Nutrition and Growth

In extremely premature neonates, use of the gut is limited initially, and therefore they must be supported at first with intravenous nutrition (*total parenteral nutrition, TPN*). As enteral nutrition is increased, the TPN is decreased accordingly. The management of premature infant nutrition is complex, requiring calculation of daily caloric, protein, fat, minerals, vitamins, and fluid needs as well as monitoring of growth and biochemical parameters. Computer applications can reduce the time spent in performing these calculations and the errors inherent in detailed information tracking. Applications that support TPN formulations have been described in the literature,[36] with demonstrated reductions in both time spent and errors.[37–40] In addition, systems have been deployed over several hospitals to extend standardization of TPN formulation.

We are entering a new era for growth and nutrition monitoring that individualizes postnatal growth by integrating perinatal, family, and postnatal data. A multitude of peri- and postnatal factors influence infants' postnatal growth to determine what is "best," according to gestational age and pathology. Determining adequacy of postnatal growth is more difficult than anticipated. An important distinction should be made between an *intrauterine growth curves* and a *postnatal growth curves*. Intrauterine growth curves describe the distribution of fetal weights based on gestational age. They can be used to determine whether a newborn is small or large for gestational age. A postnatal growth curve describes the growth in weight, head circumference, and length after birth. Superimposing the curves for premature infants reveals a striking deviation of the postnatal curve below the intrauterine curve, indicating a period of growth failure, particularly among those infants born most prematurely.[41] While the intrauterine growth curve may represent ideal postnatal growth, with the current state of neonatal care, intrauterine growth curves cannot be used to assess the adequacy of postnatal growth of premature infants.

In evaluating any standardized growth curve for use, several questions must be considered:

- From which population (ethnicity, gestational ages, socioeconomic status, etc.) was the reference standard generated?
- Does this population accurately reflect the infants whose growth will be assessed with the chart in question? For example, standard intrauterine growth curves include only Caucasian infant's from 26 to 42 weeks gestation in Denver from 1948 to 1961.[42] A more recent study using a more diverse population with larger numbers of infants at each gestational age describes birth weight percentages for

infants between 24 to 37 weeks (including a small number of infants between 22 to 23 weeks gestation).[43]
- When was the population (from which the growth curve was derived) studied? As advances in obstetrics, neonatology, and neonatal nutrition improve the care of premature neonates, recent studies may better reflect current care. For example, one of the earliest postnatal growth curves for premature infants demonstrated that 1 kg infants regained birthweight by 17 days, while a more recent curve reveals birth weight is regained much sooner (12.8 days).[41,44]

4.6 From Neonatal Care to Follow-Up Care

Ongoing care of infants requires accurate and efficient transfer of care plans and results of studies to the primary care pediatrician. The tremendous volume of information and documentation generated during a prolonged neonatal hospitalization is compounded by the fragmented nature of NICU care. An extremely premature infant may have many attending neonatologists, consultants, and trainees prior to discharge from the hospital. A major benefit of an effective information system in the NICU is the ability to locate and organize crucial information for follow-up of neonatal problems.

4.6.1 Metabolic Screening

States vary in the number of diseases included in the newborn screening panel and the number of newborn screens administered to each infant. The first sample is usually sent shortly after birth (after the first feeding) and the second sample between day 10 and 14. Samples are sent to state laboratories and results return in 1–2 weeks. Accurate and timely collection and tracking of metabolic screens is vitally important and failure may result in preventable or treatable disease with devastating complications. Regional registries, in conjunction with dedicated support personnel, can facilitate sharing of information and completion of follow-up with primary care physicians and specialists.[45]

4.6.2 Hearing Screening

Newborn hearing screens are performed prior to infant hospital discharge. NICU infants are at particular risk for hearing loss (up to 6% in one series of infants born between 500 to 750 g.[46]) Information about the necessity and timing of additional hearing tests for all infants should be transparent to parents and follow-up physicians.

4.6.3 Immunizations

Premature infants currently are covered by the same immunization schedule as term infants. A 24 week gestational age premature infant receives 2 month immunizations at a post-menstrual age of 32 weeks. It is not uncommon for very premature infants to be hospitalized for months, with multiple immunizations given in the hospital.

Palivizumab, a monoclonal antibody against respiratory syncytial virus (RSV), is recommended to prevent RSV infection in many premature infants or those with chronic lung or congenital heart disease. Eligible infants should be given as monthly injections during the RSV season, for up to the first 2 years of life.[47]

Communication of administered immunization, dates, and adverse reactions, must be communicated to the primary care physician to avoid lapses and unnecessary duplication of immunization doses.

4.6.4 Retinopathy of Prematurity

Retinopathy of prematurity (ROP) refers to the disordered growth of blood vessels supplying the developing retina. Very premature infants are at greatest risk for ROP and its sequelae because of the underdevelopment of retinal vessels. Regular eye exams by a pediatric ophthalmologist are necessary to monitor the growth of retinal blood vessels and for the development and progression of ROP. Frequency of ophthalmologic examinations is scheduled according to disease progression, the risk of complications (permanent blindness) and the need for intervention (retinal ablative surgery) to lessen the risk for retinal detachment.[48, 49] Neonatal follow-up tracking systems for premature infants should include the ability to track scheduling, completion, and reports of ophthalmology exams to the primary care physician and to parents to ensure appropriate future care.[49]

4.7 Specific Issues for Neonatal Information Systems

4.7.1 Handling Infant Name Changes

Although many infants assume the shared surname of parents, particularly if they are married, a significant portion of infants will not retain the surname initially assigned by the birth hospital. Changes in parental marital and legal status, as well as adoption, may result in infant name changes. These issues (and potential for errors) are increased with multiple gestations and infants with the same name in the same nursery, and when the infant is discharged to follow-up with the primary care

physician. NICUs and neonatal identification systems must be able to disambiguate infants, even when names are changed, in the NICU and after discharge.

4.7.2 Improving NICU Medication Delivery

The 1999 Institute of Medicine report stating that tens of thousands of patients die yearly in the US from medical errors.[50] Infants in the NICU are particularly vulnerable to errors and their impacts.

4.7.2.1 Neonatal Drug Dosing

Pediatric medications dosing is based on patient weight. The small weights of premature infants, with rapid weight and body surface area changes and variable physiologies place sick neonates at high risk for medication errors. In the NICU, preterm neonates may receive multiple medications, which increase the likelihood of errors and drug interactions. The task of prescribing in the NICU is made even more difficult by the lack of accepted dosing guidelines for medications and the high rate of "off label" medication use due to overall paucity of studies specifically looking at medication use in neonates.

NICU medication errors commonly occur at the ordering stage. Extremely premature (low weight) infants are at risk for decimal place errors in dosing, that can be exacerbated with poor handwriting. In addition, many neonatal drugs are dispensed in vials from which very small amounts of drug must be withdrawn, which enable order of magnitude errors in ordering and administration.[51] Medication ordering error frequencies appear to be inversely proportional to body weight,[52] with 71% of errors occurred at the prescribing and 29% of errors at administration.[51] The two most common types of errors were incorrect dose and dosing interval, with increased rates of dosing errors occurring when new housestaff rotated through the NICU.

Additional risks for errors are incurred with complex calculations, such as discussed previously for continuous infusion ("drips") and total parenteral nutrition.[33] In addition to calculators, standard concentrations for continuous infusions,[53] with smart-pump technology and improved medication labeling have been associated with marked decreases in continuous infusion errors.[54]

Quality improvement in medication delivery demands consideration of the entire delivery process rather than independent events. *Failure mode and effects analysis* (FMEA), a quality improvement technique developed in industry to improve safety, has identified general lack of awareness of medication safety, problems with administration and ordering of medications to be the most significant issues in NICU medication delivery.[55]

Integration of information technology into ordering, dispensing, and administration of medications in inpatient environments is examined in Chapter 26.

4.7.2.2 Delivering Drugs in Emergencies: The Code Card

Code Cards detail specific emergency medications and their doses according to weight in both milligrams and milliliters to be given during resuscitations. During neonatal resuscitation, drug doses are ordered, drawn from stock vials and administered emergently, and errors may easily occur. A preterm infant's weight may change markedly over a short period of time, and therefore, code cards must be updated frequently. One benefit of computer-generated code cards (that can be created using commercially available software, such as a spreadsheet) is automated updating, especially if the dosing is linked to the current weight (from an electronic record), or as part of the regular care routine.

4.8 Conclusion

Though medicine has been late to incorporate computers into daily routines, use of computers in neonatology is growing. Linkage with obstetrical information systems can streamline entry of information into the neonate's record. Growth may be more easily monitored. Crucial information for follow-up physicians can be easily tracked and synthesized into discharge summaries. Patient safety can be enhanced by decreasing errors in medication and TPN orders. As obstetricians, neonatologists, nurses, and pharmacists increasingly incorporate computer systems, a major challenge will be to synthesize these systems into a cohesive outpatient and inpatient network.

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