Chapter

1

Introduction to Care of Newborn Babies

Infants between birth and first 28 days of life are called newborns or neonates. They truly constitute the foundation of human life. *Just as children are not mini-adults, neonates are not mini-children.* They have unique health issues and problems due to structural and functional immaturity of various body organs depending upon their gestational age and birth weight. Newborn period is the most vulnerable phase of life and deaths during first 28 days of life account for around 70% of all infant deaths and 56% of all deaths of under-5 children.

Most healthy term neonates can be managed at home under the guidance and supervision of mother or health care professional. On the other hand, low birth weight and premature babies are fragile and vulnerable, and they demand high degree of skills and technology in a special care nursery or neonatal intensive care unit (NICU) for their intact survival. Apart from high neonatal mortality rate of 22.7 per 1000 live births, many avoidable handicaps during childhood, such as cerebral palsy, mental subnormality, learning disabilities and recurrent seizures, have their origin in the perinatal period. Based on "thrifty gene" or "developmental origins of adult diseases" hypothesis by Barker, there is evidence to suggest that infants with intrauterine growth restriction are at an increased risk to develop certain adult-onset diseases like hypertension, coronary artery disease, obesity, type 2 diabetes mellitus and hyperlipidemia. *The aim and goal of newborn care is not only to reduce neonatal mortality but more importantly to ensure their intact survival.* The enhancement of neonatal and infant survival is truly the key to the success of family welfare program and stabilization of population dynamics. And to achieve that goal, the task must be pursued like a mission.

EVOLUTION OF NEONATOLOGY

The concept and practice of neonatology evolved about 50 years ago and since then we have made outstanding advances in the care of newborn babies. It is amazing that a newborn baby with a birth weight of 1.0 kg had a mortality risk of 95% in 1960 and now has a 95% probability of survival! Neonatology has evolved from a state of passive or "hands-off years" (1920–1950) through aggressive or "heroic years" (1950–1970) and has reached a phase of "experienced years" (1970–2000) by promoting evidence-based neonatology. Due to integration of science and art of newborn care, the practice of neonatology has now reached the "years of wisdom" (middle path concept) and focus has shifted from mere survival to "intact" survival. Major advances in neonatology include effective resuscitation at birth, prevention of hypothermia and infections, rational use of antibiotics and promotion of optimal nutrition with human milk and parenteral nutrition. Availability of microsampling of blood has ensured frequent monitoring and correction of abnormalities in blood gases, acid–base parameters, electrolytes, glucose, bilirubin and other biochemical parameters. It is possible to monitor vital signs and arterial oxygen saturation with the help of noninvasive technology. The outcome and survival of preterm babies has improved by use of antenatal corticosteroids, administration of exogenous surfactant, and respiratory support (CPAP, assisted ventilation, iNO, ECMO). Pharmacological manipulation of ductus arteriosus, support of blood pressure, portable or point-of-care echocardiography, use of inhaled nitric oxide (iNO), interventional cardiology, newer modalities of assisted ventilation (PTV, SIMV and high frequency ventilation) and extracorporeal membrane oxygenation (ECMO) have revolutionized the cardiopulmonary management

of critically sick neonates. Phototherapy has reduced the need for exchange blood transfusions and risk of bilirubin encephalopathy. A number of therapeutic misadventures or disasters of our good intents, like retinopathy of prematurity (ROP), pulmonary air leaks, bronchopulmonary dysplasia (BPD), kernicterus (sulfisoxazole prophylaxis, synthetic vitamin K, novobiocin), "gray-baby" syndrome (chloramphenicol over dose), pyloric stenosis (prokinetics like erythromycin), intraventricular hemorrhage (aggressive handling, bolus administration of sodium bicarbonate), cerebral palsy (corticosteroids) and pumonary air leaks, due to aggressive assisted ventilation are prevented or recognized early and managed effectively. It is important that we must exercise restraint and caution while introducing newer therapeutic interventions while keeping in mind their safety and cost effectiveness.

THE ART OF NEONATOLOGY

"The art of newborn care should not be sacrificed at the altar of technology. Art and science should provide an hormonious blend to ensure holistic care".

Meharban Singh

The technology has revolutionized the practice of neonatology and we have moved from an exceedingly "passive" or gentle hands-off approach to an over enthusiastic technology-oriented "aggressive" or "robotic" approach. It is a sad reality that nobody knows the ultimate or absolute truth. Science only provides a tentative or partial truth or truth for the time being. Neonatology is dynamic and we are likely to find new facts and data in due course of time. Therefore, we should not be dogmatic and we must work with humility, common sense and compassion. Evidence-based neonatology or Cochrane data base is probably closest to the truth but it must be integrated with personal experience or expertise, and common sense to transform these recommendations into best neonatal practices in order to harness best dividends. It is better to adopt and follow a balanced "middle path" approach in the care of newborn babies instead of having an extremely passive or balatantly aggressive approach. We should exercise restraint with a checks and balances on the pace of change to ensure that the knowledge is transformed into wisdom and it should be effectively harnessed keeping in mind the existent social constraints and realities. Technology should not be allowed to further dehumanize neonatology and we must treat babies not only with our heads but also with our hearts. Babies should be provided comfort, cuddling and gentle care by promoting best newborn care practices which are safe and cost-effective. We should not merely try to satisfy our ego in trying to save "previable premies" but our aim should be to ensure their "intact survival" so that the baby grows to become an asset to the nation rather than a liability to the society. Every newborn unit must have an integrated follow-up program to assess the quality of life of their NICU graduates and provide them with early stimulation.

In the best pediatric tradition, the approach in perinatal medicine should be oriented towards prevention, early identification and prompt management of common perinatal disorders. The art and science of newborn care should be integrated to provide holistic care to preterm babies. Babies should not be handled as "objects" and instead they should be provided with humanized developmentally supportive care. The nurses should provide individualized supportive care to preterm babies by adopting a "flexible" approach. They should feel connected and tuned with babies under their care. All the health care professionals in the neonatal intensive care unit (NICU) should be gentle, considerate and compassionate in providing care to preterm babies. The nature is supreme the way it looks after all the needs of the baby in the womb. The physiological needs of comfort, protection (against hypothermia and infection), oxygenation, nutrition and excretion are admirably met by the uteroplacental unit. *Womb is our gold standard for care of preterm babies and we should try to create a baby-friendly womb-like ambience and ecology in the NICU.* Despite several attempts, scientists have failed to fabricate an incubator with all the qualities and characteristics of the womb.

MATERNAL HEALTH AND NEWBORN SURVIVAL

Mothers are the creators and sustainers of progeny. The health and wellbeing of children is intimately linked with the health, nutrition, education and status of their mothers. Healthy and well-informed mothers are likely to produce healthy and normal weight babies while undernourished and high-risk mothers are likely to produce high-risk and low birth weight babies. Healthy mothers are in a much better position to look after the health and wellbeing of their children. Nutrition during fetal life and early infancy (exclusive breastfeeding) is entirely transmaternal and

"The health and wellbeing of the fetus is dependent upon the health and nutrition of the mother (not the father!) because she is both the seed as well as the soil wherein the baby is nurtured for 9 months".

Meharban Singh

its adequacy depends upon the nutritional status of the mother. *Mother is the best primary health worker because of her strong motivation, concern and commitment*. She must be provided with information, knowledge and skills of mothercraft to handle her baby with ease and confidence. She can provide skin-to-skin contact or kangaroo mother care which is credited to reduce the risk of nosocomial infections and hypothermia with improved survival of LBW babies. Over one-third of women in India are undernourished with a body weight of less than 40 kg or height of less than 145 cm. They are prone to develop a variety of infections, genital colonization, bacterial vaginosis with high prevalence of pelvic inflammatory disease and unsatisfactory reproductive health. Around one-half of women in our country are illiterate, they lack personal and financial independence and empowerment. The situation is further complicated by early marriages, teenage and frequent pregnancies. Despite Child Marriage Act 1978, almost 30% girls in India are married off before the age of 18 years without their consent. No wonder every fourth baby is a low birth weight in our country. In India, antenatal care of questionable quality is available to 85% of pregnant women and less than 50% of deliveries are conducted by skilled birth attendants.

GLOBAL NEONATAL HEALTH

Globally 130 million babies are born every year and of these 4 millions die during the newborn period, i.e. first 4 weeks of life. A similar number of babies are stillborn accounting for 8 million perinatal deaths per year, i.e. 15 lives are lost every minute. Most neonatal deaths occur in first week of life (75%) and almost 25% during first 24 hours. The risk of mortality during neonatal period is 30-fold higher than during the post-neonatal period. Almost 99% of neonatal deaths occur in low-middle income countries (LMICs). India accounts for the highest number of annual births (26 million) and neonatal deaths (0.75 million or 30% of global burden). Neonatal deaths account for two-thirds of all infant deaths and 56% of under-5 child deaths. The millennium development goal 4 (reducing under-5 mortality by two-thirds) cannot be achieved without substantial reduction in neonatal mortality. The situation is further worsening due to global epidemic of HIV and COVID-19. According to analysis of 3.6 million neonatal deaths from 192 countries in 2010, the main direct causes of neonatal deaths include preterm births (29%), severe infections (29%), birth asphyxia (23%) and congenital malformations (8%). The direct causes of global neonatal deaths are listed in Figure 1.1. The common correlates of adverse neonatal outcome include poor health status of women, illiteracy, lack

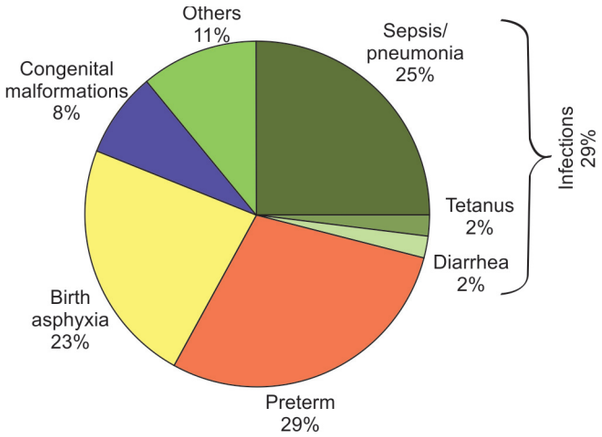

Figure 1.1 Estimated distribution of direct causes of global neonatal deaths (Adapted from Lawn JE, Cousens S, Zupan J. 4 million neonatal deaths: When? Where? Why? *The Lancet* 2005, 365:891–900.

of empowerment, early marriages and frequent pregnancies. In developing countries, lack of resources, poor infrastructure, lack of antenatal care, deliveries by unskilled attendants or relatives and poor accessibility and credibility of the facility-based health care services are the leading causes of dismal situation of newborn health.

MYTHS AND MISCONCEPTIONS REGARDING NEWBORN CARE

There are a number of myths and misconceptions regarding newborn care which can discourage health care professionals in initiating effective interventions to improve newborn survival.

1. *Newborn mortality can be reduced only by developed countries with high gross domestic product* (*GDP*): Several countries with low GDP, like Sri Lanka, Indonesia, Vietnam, Cuba, Honduras, and Nicaragua, have reduced neonatal mortality rates (NMR).
2. *High-tech interventions are needed to improve newborn survival*: Many countries have reduced NMR to about 15 per 1000 live births with community-based interventions without use of complex technology. There are minimum technology needs for care of newborn babies in the community (Box 1.1).
3. *Newborn care is expensive and not cost-effective*: Several low-cost interventions are effective to reduce neonatal mortality, like administration of tetanus toxoid to pregnant women, exclusive breast-feeding, kangaroo mother care for LBW babies, prevention and early use of antibiotic therapy for prompt treatment of infections.

Box 1.1 The technology needs for care of newborn babies in the community

- Birth attendant "disposable delivery kit"*.
- Mask for providing mouth-to-mask resuscitation.
- Five cleans (surface, hands, blade, cord tie, cord care).
- Promotion of early and exclusive breastfeeding.
- Home-based strategies for prevention of hypothermia (postpone bath, provide effective clothing, closeness with mother, warm room, external heat source).
- Kangaroo mother care.
- Ensuring hygienic practices (hand washing skills, clean blade, cord care, clean environment, clean sun-dried clothes).
- Gavage and spoon or *paladay* feeding of LBW babies.
- Availability of oral and injectable antibiotics.
- Distribution of information, education and communication (IEC) material on care of normal and LBW babies and identification of sick babies (danger signs).

*According to NFHS-4, disposable *dai kit* was used in 50% of home deliveries.

4. *Newborn health is not a priority in a developing country because high neonatal mortality is a blessing in disguise to control population dynamics*: Newborn survival is indeed the greatest assurance and incentive to parents to adopt family planning measures and achieve desired population goals.
5. *Neonatal-specific interventions are not needed because current safe motherhood and child survival strategies are sufficient to reduce deaths of newborn babies.*

Till recently, Child Survival and Safe Motherhood (CSSM) and Reproductive and Child Health (RCH) programs focused on reduction of post-neonatal deaths by promotion of breastfeeding, immunizations, ORS for treatment of diarrhea and antibiotics for acute respiratory infections. The need for specific neonatal interventions is being addressed in India by launch of Integrated Management of Neonatal and Childhood Illnesses (IMNCI) program and India Newborn Action Plan (INAP) so that newborn diseases are tackled through simple algorithms. There is a need to create a network of good quality level II newborn care units throughout the country which are more cost-effective and less technology or labor-intensive and can bring down the neonatal mortality rate to less than 20 per 1,000 live births.

ESSENTIAL NEWBORN CARE

Every year about 26 million babies (20% of global births) are born in India and almost 0.75 million die during newborn period accounting for 30% of global deaths. *India has the dubious distinction of having the highest number of annual neonatal births and deaths among all countries in the world.* In order to reduce neonatal mortality, essential or basic newborn care services should be available at all the health care levels because they are highly cost-effective. The components of essential newborn care services include good quality antenatal care (at least 4 ANC contacts), safe delivery and optimal care at birth, promotion of exclusive breastfeeding, prevention and early treatment of hypothermia and bacterial infections. The moderately low birth weight babies (birth weight >1800 g) and/or late preterms with a gestation >34 weeks account for 90% of LBW babies and they should be provided essential care at home or primary health care facility. There is a need for greater focus on the preventive rather than curative strategies because a large number of neonatal deaths occur due to potentially preventable disorders, like birth asphyxia, hypothermia and septicemia. The provision of essential newborn care is the most urgent key health care priority in our country and saving newborn babies in India is a national priority in order to achieve further reduction in infant mortality rate.

NEONATAL MORBIDITY

The health problems of newborn babies are unique and distinctive compared to diseases of infants and older children. Neonates are prone to develop health problems due to transition from dependent fetal to independent neonatal physiology, disorders due to structural and functional immaturity of various body organs and a variety of iatrogenic disorders because of aggressive use of technology in the NICU. The salient health problems of newborn babies are listed below.

"The seeds of neonatal morbidity are sown in the labor room".
Meharban Singh

1. **Disorders due to unsatisfactory adaptation from fetal to neonatal physiology** Fetus is totally dependent and at the mercy of placental integrity and maternal wellbeing. After birth, baby must breathe, clear all the fluid from the lungs and promptly make a change over from fetal to neonatal cardiorespiratory physiology for survival. Birth asphyxia, wet lungs (transient tachypnea of the newborn), patent ductus arteriosus and persistent pulmonary circulation are some of the manifestations of unsatisfactory transition from fetal to neonatal physiology.
2. **Disorders of body temperature** Most babies rapidly lose body temperature because they are

born naked and wet and they come from a warm womb to a cold room. If a baby is not promptly dried or effectively covered or kept under a radiant warmer, he is likely to develop hypothermia and its consequences. Fever is the commonest signal of infection in a child, while a neonate, especially a preterm baby, may succumb to sepsis without exhibiting any fight and instead becomes sluggish, cold and apneic.

3. **Vulnerability to infections** Newborn babies are extremely vulnerable to develop bacterial infections because from a relatively aseptic uterine abode they make entry into a room which is teeming with microbes. They are endowed with suboptimal immunologic responses with a relatively poor localization of infection leading to sepsis and adverse outcome. Some babies may be born with intrauterine infections (TORCH infections) or develop infection during their passage through the infected birth canal leading to development of early-onset sepsis. Most neonatal infections are nosocomial and are acquired from the hospital or from the community.
4. **Respiratory difficulties** Idiopathic respiratory distress syndrome or hyaline membrane disease due to deficiency of surfactant is limited to preterm babies. Availability of surfactant and assisted ventilation facilities have improved the survival of premature babies. Apneic attacks due to immaturity of respiratory center is also limited to preterm or sick babies. Meconium aspiration syndrome is an important cause of RDS in post-term or growth-retarded term babies with placental dysfunction. Premature babies are prone to develop aspiration of feeds in the absence of skilled nursing.
5. **Gastrointestinal disorders** Incoordination between sucking and swallowing, and laxity of gastroesophageal sphincter may lead to intolerance of oral feeds, frequent episodes of regurgitation and aspiration into the lungs. Necrotizing enterocolitis due to GI stasis and poor motility of gut is known to occur in preterm babies.
6. **Cardiac disorders** Congenital cardiac malformations may present as congestive heart failure or shock as a life-threatening emergency in newborn period. Many cardiac malformations are duct-dependent and palliative relief can be provided by administration of prostaglandins. Functional patency of ductus arteriosus, which can be managed with medical therapy, is peculiar to preterm babies having RDS.
7. **Neonatal jaundice** The causes and spectrum of jaundice in newborn babies are unique compared to older children. Almost two-thirds of neonates manifest physiologic jaundice which does not need any investigations or treatment. Hyperbilirubinemia due to blood group incompatibility between the mother and her baby (Rh or ABO system) is unique to newborn babies. Hyperbilirubinemia due to elevated levels of unconjugated bilirubin may seep through the blood–brain barrier and cause damage to basal ganglia (acute bilirubin encephalopathy or kernicterus). It is managed by unique therapeutic modalities, like phototherapy and exchange blood transfusion which are not applicable to older children. Jaundice (with some elevation of direct bilirubin) may occur as a manifestation of urinary tract infection, sepsis and cholestasis in neonates. Some breast-fed babies may develop prolonged jaundice (breast milk jaundice) which is harmless and does not need any therapy. Viral hepatitis is the commonest cause of jaundice in an older child while it is rare in a newborn baby.
8. **Hematological problems** Because of relative hypoxia during fetal life, average hemoglobin in newborn babies is around 16–18 g/dL with a high risk of symptomatic polycythemia and hyperviscosity. Hemorrhagic disease of the newborn due to vitamin K deficiency is limited to newborn babies. Disseminated intravascular coagulation (DIC) is a common complication in critically sick, hypoxic and hypotensive preterm babies.
9. **CNS disorders** There is high incidence of seizures in newborn babies due to hypoxia, hypoglycemia, birth trauma, sepsis and congenital malformations. Unlike older children, most seizures are symptomatic rather than idiopathic. Intraventricular hemorrhage due to immaturity of capillaries is limited to preterm babies. Administration of corticosteroids in newborn babies may lead to neuronal damage with increased risk of cerebral palsy. The seeds of cerebral palsy and neuromotor disorders during childhood are sown in the perinatal period.
10. **Congenital malformations** Congenital malformations, developmental defects, chromosomal disorders and inborn errors of metabolism due to genetic defects are limited to newborn babies and infants.
11. **Iatrogenic disorders** Because of liberal use of technology and greater vulnerability of neonates,

the incidence of disasters due to acts of omissions and commissions by doctors and nurses is much higher during neonatal period. Iatrogenic disorders may occur due to administration of drugs (kernicterus due to administration of vitamin K and sulfisoxazole, gray baby syndrome due to chloramphenicol, deafness due to aminoglycosides, intraventricular or pulmonary hemorrhage due to bolus administration of intravenous sodium bicarbonate), oxygen therapy (ROP and bronchopulmonary dysplasia) and procedures (premature delivery, skin burns, necrotizing enterocolitis, pneumothorax, bronchopulmonary dysplasia, electric shock, etc.).

THE LEVELS OF NEWBORN CARE

Based upon birth weight and gestational age, a three-tier system of neonatal care is proposed for developing countries.

Level I Care

Over 80 percent of newborn babies require minimal care which can be provided by their mothers under the supervision of basic health care professionals. Neonates weighing above 1800 g or having gestational maturity of 34 weeks or more (late preterms) belong to this category. The care can be provided at home, subcenter and primary health center level. Basic care at birth, provision of warmth, maintenance of asepsis and promotion of exclusive breastfeeding form the mainstay of level I care. Traditional birth attendants and community health workers must be trained in the art of esssential perinatal care.

Level II Care

Infants weighing between 1200 and 1800 g or having gestational maturity of 30–34 weeks need specialized neonatal care supervised by trained nurses and pediatricians. First referral units, district hospitals, teaching institutions and nursing homes should be equipped to provide intermediate neonatal care. Equipment for resuscitation, maintenance of thermoneutral environment, intravenous infusion and gavage feeding, phototherapy and exchange blood transfusion should be available. There should be no compromise on the basic needs of adequate space, nursing staff and maintenance of asepsis including round the clock handwashing and hand sanitization facilities, provision for disposable gamma-irradiated suction catheters, feeding tubes, endotracheal tubes, and small-vein infusion sets. Intermediate neonatal care is needed for about 10 to 15% of newborn population and should be available at all hospitals catering to 1000 to 1500 deliveries per year.

Level III Care

Intensive neonatal care is required for babies weighing less than 1200 g or those born before 30 weeks of gestation. Apex institutions or regional perinatal centers equipped with centralized oxygen and suction facilities, servo-controlled open care systems and incubators, vital sign and transcutaneous monitors, ventilators and infusion pumps are best suited to provide intensive neonatal care. Skilled nurses and neonatologists especially trained in the art of neonatal intensive care are required to organize this service. About 3 to 5% of newborn population qualify for intensive care. Establishment of neonatal intensive care unit (NICU) demands a sound infrastructure and should be envisaged only when optimal intermediate neonatal care facilities have already been in existence for some time. The capital and recurring expenditure for level III care is exorbitant and it is not cost-effective unless service is regionalized.

IMPROVING THE QUALITY OF MATERNAL AND NEWBORN CARE

World Health Organization has launched a global initiative to improve quality of maternal and neonatal health care, especially in the low and middle income countries (LMICs). The improvements in the quality of health care are essential to meet the health-related targets of the Sustainable Development Goals (SDGs). The quality assurance (QA) and quality improvement (QI) efforts are crucial for improving the maternal, fetal, neonatal and child survival at all levels of health care. The QI initiative aims to increase the probability to provide safe, timely, effective, equitable and patient-centered health services to mothers and their offsprings. The "Every Newborn Action Plan" (ENAP) and Ending Preventable Maternal Mortality (EPMM) initiatives have been launched to end all preventable maternal and neonatal deaths and stillbirths by 2035. Monitoring the performance of the health care system and implementation of quality improvement activities need reliable systems for data collection, analysis and interpretation.

India and other LMICs have launched QI initiatives for providing safe, effective, patient-centered and equitable maternal and neonatal health care services at various levels of health care facilities. World Health Organization has provided an eight-point directive to provide quality assured services in the field of maternal and perinatal health. These domains include (i) evidence-based practices for essential care of mothers and their children, (ii) early recognition of

complications and their management, (iii) actionable information system, (iv) robust referral system, (v) effective communication, (vi) respect and dignity, (vii) emotional support with the help of (viii) motivated human resources and functional health care infrastructure. A conceptual framework is useful to develop QI parameters in the field of health care. The framework proposed utilizes two approaches for delivery of good quality health care. The Donabedian model divides the health care into structure, processes and outcomes, while the Institute of Medicine's (IOM) initiatives focus on the needs to provide *safe*, *timely*, *effective*, *efficient*, *equitable* and *people-centered* health care services.

The QI Initiatives

The QI approaches try to narrow the gap between current knowledge and actual practices in various health care facilities. They share four core principles. First, to identify the gap between expected outcomes of various clinical situations versus the actual outcomes achieved by the first-line health workers providing the clinical care. Second, understanding the local health care systems to identify various barriers preventing delivery of quality health care. Third, to implement the classic problem-solving small steps of change under the format of Plan-Do-Study-Act (PDSA). To initiate the cycle of change under PDSA, the intervention is Planned, it is carried out (Do), its outcome is evaluated (Study) and whether any modifications are required for the intervention (Act). The PDSA intervention should be feasible, effective and adaptable in the local context before it is launched for universal implementation. Fourth, the salient health problems should be identified on the basis of available data and to assess whether interventions are achieving their objectives. Various health care issues can be studied under PDSA to promote the concept of QI. Various outcomes of quality measures like vision, hearing, neuromotor disability, seizures, etc. can be studied to achieve best dividends.

The Health Care System

The health care system includes essential physical infrastructure and availability of adequate number of competent health care providers. Shortage of skilled manpower is an important correlate of poor quality of care in the LMICs. The quality of care can be improved by providing adequate physical and human resources. The facility-based resources should be specifically tailored to prevent and manage prematurity, infections and perinatal asphyxia, which are three leading causes of neonatal morbidity and mortality in LMICs. The framework of quality improvement of perinatal services is summarized in Box 1.2. The performance of health care system, the success and failure of QI efforts is largely dependent on availability of health care workers, their motivation level, burnout, teamwork and leadership skills.

Health Care Processes

The vision of World Health Organization for improvement of quality of care of mothers and there children is summarized in Figure 1.2. The QI depends on availability of sound health infrastructure, and evidence-based processes to ensure improved outcomes. The components of health care processes in neonatal resuscitation include identification of neonates who need resuscitation, the need for positive pressure ventilation, criteria for adequacy of bag and mask ventilation and administration of drugs. Data about health care processes are best measured by direct observations. However, this is prone to Hawthorne effect wherein alteration of behavior is likely to occur when it is known that you are being observed. The Hawthorne effect should be reduced by installing CCTV cameras and monitoring by regular staff members. Data about processes can be retrieved from digital records and personal interviews.

Box 1.2 The framework for quality improvement of perinatal services

- Establish core set of essential perinatal services at all levels of health care facilities.
- The WHO has outlined a set of quality of care indicators and standards for improving quality of maternal and newborn health care facilities. These standards and indicators can be adapted on the basis of national needs.
- There is a need to establish the processes for measurement of core set of quality of care indicators for neonatal-perinatal care.
- There should be a robust system of data collection for perinatal morbidities and outcomes by establishing state level and national level neonatal-perinatal quality monitoring and improvement of resource facilities.
- The existing health information management systems and digital electronic patient record systems should be modified to include quality of care indicators.
- There is a need to develop quality improvement activities by incorporating QI training in pre- and in-service curriculum for assessment of quality of care on a day-to-day basis, quarterly and yearly appraisal.

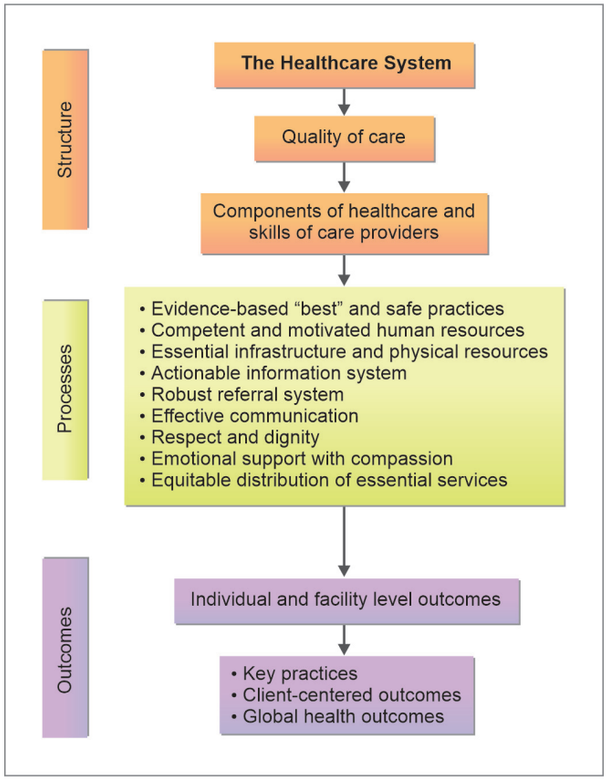

Figure 1.2 WHO vision for quality of care of mothers and their neonates

Health Outcomes

The morbidity and outcome of a disease process is the best parameter of quality of care. Apart from adequacy of preventive and curative health care services, genetic predisposition, developmental abnormalities, environmental exposures and care-seeking behavior influence the outcomes. Examples of health care outcomes in neonatal care include incidence of morbidities like hypoxia, RDS, infections, hypothermia and hypoglycemia. The parameters of quality improvement of perinatal services are summarized in Box 1.2. The health care facilities and monitoring agencies should invest in collection and analysis of reliable data to assess the dividends of quality assurance and quality improvement activities.

Future Developments and Perspectives

A large number of newer interventions are in the pipeline to further revolutionize the practice of neonatology. A number of multicentric randomized controlled trials (RCTs) have been launched to identify evidence-based, reliable, and safe newborn care practices. Skin surface electrodes are being developed for non-invasive monitoring of blood gases, glucose, bilirubin, electrolytes and pH. There is a need to develop ultramicrotechniques for assessment of complete biochemical parameters with the help of a drop of blood. Newer diagnostic techniques with the help of polymerase chain reaction (PCR) are being developed for the diagnosis of a variety of infective and genetic disorders. Neonatal screening for inborn errors of metabolism is likely to become universal. Efforts are being made to develp specific monoclonal antibodies for prevention and treatment of life-threatening infective disorders. There is availability of a variety of sophisticated lasers for treatment of birth marks. Vaccines are being developed for prevention of Group B streptococci (GBS), cytomegalovirus (CMV), human immunodeficiency virus (HIV) and novel coronavirus infections. Tailor-made drugs are being formulated with the help of pharmacogenetics and attempts are being made to deliver the drugs to the site of disease with the help of liposomes.

There is increasing use of homologous blood obtained from placenta and possibility of storing cord blood has become a reality for future use as "totipotent" stem cells for repair of any organ and treatment of malignant or genetic disorders in the donor, siblings or parents. Genetic engineering is being exploited to replace a "bad" gene with a "good" gene by tagging it to the carrier viruses. Assisted reproductive technologies (ARTs) are being harnessed to produce genetically normal babies, flawless designer babies, surrogacy and gender selection raising several moral and ethical issues. There is a need to develop strategies to prevent premature birth of babies who are structurally normal. Prolongation of gestation and improvement of fetal nutrition are important interventions to improve birth weight which is the single most important correlate of improved survival and outcome of a neonate. However, the ultimate dream of a neonatologist, which has defied all attempts till date, is to prevent premature births to improve the birth weight and to develop a prototype of a uteroplacental unit to provide all the virtues of the womb to nurture babies who are born prematurely.

NOMENCLATURE AND DEFINITIONS

It is essential to have uniformly accepted definitions to express perinatal–neonatal morbidity and mortality. The data pertaining to perinatal audit should conform to a universal format for ease of comparison with other national and international studies. The adoption of standard nomenclature is essential for generating meaningful data and for surveillance of impact of

interventional strategies. Accuracy of record keeping is mandatory for generation of meaningful data for perinatal audit. The data is collected from antenatal records, specialized neonatal proformas and admission/discharge registers. It is essential to maintain separate registers for NICU (one each for intramural and extramural babies) and rooming-in babies. A software should be created to store the data in the computer. The data should be checked and reviewed weekly, monthly and yearly in the joint meetings between the staff members looking after the mothers and babies. The analysis and retrieval of data can be greatly augmented by computer facilities. The majority of definitions and terminologies described below are based on the standard sources, such as tenth revision of International Statistical Classification of Diseases (ISCD) by WHO and they are duly approved and adapted by the Taskforce of National Neonatology Forum of India.

Fetus

Fetus is a product of conception, irrespective of the duration of pregnancy, which is not completely expelled or extracted from its mother. Up to 9 weeks of gestation, it is designated as embryo.

Live Birth

Live birth is defined as complete expulsion or extraction from the mother of a product of conception (irrespective of the duration of pregnancy) and which after such separation, breathes or shows any other evidence of life, such as beating of the heart, pulsation of umbilical cord or definite movements of the voluntary muscles irrespective of the attachment of placenta and/or cord. In a community setting, cry and breathing efforts alone may be used as a criterion of live born. In 1970, WHO recommended that babies weighing less than 500 g at birth should show signs of life for at least one hour before they are designated as live born.

Fetal Death

Death prior to the complete expulsion or extraction from its mother of a product of conception irrespective of the duration of pregnancy, the death being indicated by absence of any signs of life.

Early fetal death Death at a gestational age of less than 22 weeks or of a fetus weighing less than 500 g or crown-heel length of less than 25 cm.

Intermediate fetal death Death at a gestational age of 22–27 weeks or of a fetus weighing 500–999 g or crown-heel length between 25 cm and less than 35 cm.

Late fetal death Death at a gestational age of 28 weeks or more or of a fetus weighing 1000 g or more or crown-heel length of at least 35 cm. The body may be fresh or macerated.

Early fetal deaths are called abortions while intermediate and late fetal deaths are designated as stillbirths.

Birth Weight

Birth weight is the first weight of a live or stillborn baby which should preferably be taken within the first hour of life and certainly during the first day of life before any significant postnatal weight loss has occurred. If weight is recorded after 24 hours, the age at which the weight is taken should be specified. The average birth weight of newborn babies in India is around 3.0 kg.

Birth Weight Groups

Low birth weight (LBW) babies Babies with a birth weight of less than 2500 g (up to and including 2499 g) irrespective of the period of gestation are designated as LBW babies. These include preterm (one-third) and small-for-dates term (two-thirds) babies. In India, for purposes of according specialized care, babies with a birth weight of less than 1800 g are considered as high risk and are admitted to the special care neonatal unit (SCNU). The current incidence of LBW babies in India is around 28% (lowest incidence of 7.6% in Mizoram) accounting for 8 million LBW babies (40% of global burden) every year. However, over 80% of LBW babies are good-sized and weigh between 2000 and 2499 g, and 15% infants weigh between 1500 and 1999 g.

Very low birth weight (VLBW) babies Babies with a birth weight of less than 1500 g (up to and including 1499 g) are designated as VLBW babies. In India, around 3% babies are VLBW babies.

Extremely low birth weight (ELBW) babies Babies with a birth weight of less than 1000 g (up to and including 999 g) are classified as ELBW babies. They account for <1.0% of all live births.

Micropremies Infants with a birth weight of less than 750 g.

Gestational Age

Gestational age is calculated from the first day of the last normal menstrual period till the date of birth and is expressed in weeks and days. For example, 30 2/7 weeks of pregnancy means 30 completed weeks plus 2 days. It is also called menstrual age. On the other hand, the conceptional age is the true fetal age and it refers to the length of pregnancy from the time of conception and is generally 2 weeks less than the menstrual age.

Gestational Age Groups

The American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal and Fetal Medicine have revised the classification based on the gestational age.

Preterm (premature) Neonates between 20 weeks and 36 6/7 weeks (<37 completed weeks) are classified as preterm. Around 10–15% babies are born preterm in India.

Late preterm 34 0/7 weeks through 36 6/7 weeks of gestation.

Extremely preterm Babies born before 28 completed weeks of gestation.

Full term (or "Term") Babies between gestational age 39 0/7 weeks through 40 6/7 weeks. According to new definition, a pregnancy is "full term", only in the narrow two-week window between 39 and 41 weeks. The outcome of babies is best during this narrow window. It is recommended that elective cesarean section should not be done before 39 weeks of gestation.

Early term Babies between 37 0/7 weeks through 38 6/7 weeks of gestation.

Late term Babies between 41 0/7 weeks through 41 6/7 weeks of gestation.

Post term Babies with a gestation of 42 0/7 weeks and beyond are classified as post term and postmature.

Classification by Birth Weight and Gestational Age Groups

Small-for-dates (SFD) babies (Small-for-gestational age, light-for-dates). Babies with a birth weight of less than 10th percentile for their gestational age population-based weight data are designated as SFD babies. For purposes of specialized care and monitoring of blood glucose levels, babies with a birth weight of less than 3rd percentile for the period of their gestation are admitted in the NICU.

Ideally, regional intrauterine growth charts should be constructed from a population belonging to high socioeconomic level with optimal maternal nutrition, and after excluding known maternal and fetal conditions, which cause intrauterine growth retardation. It also appears justified to employ one universally accepted international reference standard for purposes of comparison of the data. The terms intrauterine growth restriction (IUGR) and small-for-gestational age (SGA) are often used interchangeably but they are actually distinct. The fetus is diagnosed to have growth restriction, if the intrauterine growth is less compared to the predetermined growth potential of healthy fetuses. An infant with IUGR may be SGA or his birth weight may be appropriate-for-gestational age.

Appropriate-for-dates (AFD) babies (Appropriate-for-gestational age). Babies with a birth weight between 10th and 90th percentile for the period of their gestation are called appropriate-for-dates babies.

Large-for-dates (LFD) babies (Large-for-gestational age, heavy-for-dates). Babies with a birth weight of more than 90th percentile for the period of their gestational age. The babies with a birth weight of more than 97th percentile for their gestation are considered high risk and monitored for hypoglycemia.

By combining classification of the babies on the basis of gestational age alone and gestational age with birth weight, the newborn population can be divided into the following 9 subgroups (Figure 1.3).

1. Preterm	SFD, AFD, LFD
2. Term	SFD, AFD, LFD
3. Post-term	SFD, AFD, LFD

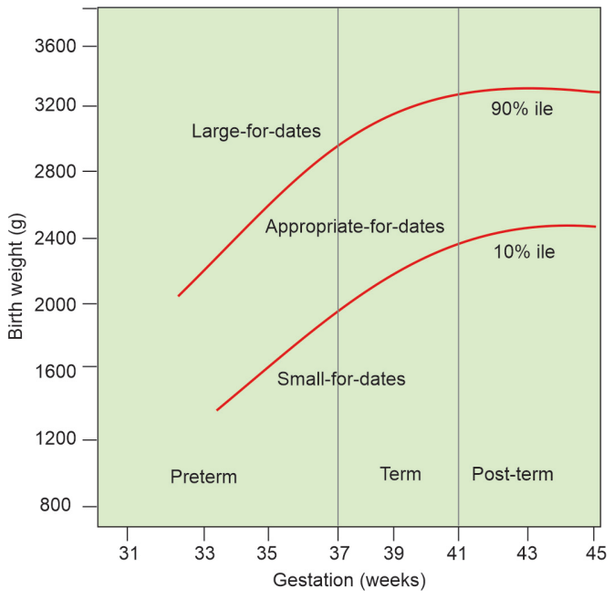

Figure 1.3 Classification of neonates on the basis of birth weight and gestational age. (Adapted from Singh M, Giri SK and Ramachandran K. *Indian Pediatr* 1974,11:475)

The neonatal mortality is high among preterm babies due to anatomical and functional immaturity of various body organs. The least neonatal mortality is seen in term appropriate-for-dates babies. In each gestational group (whether preterm, term or post-term), mortality is higher among LFD and SFD babies as compared to AFD babies.

Perinatal Period

Perinatal period extends from the 28th week of gestation (or more than 1000 g) to the 7th day of life (early neonatal period). In view of the increasing survival of the babies weighing less than 1000 g in many centers as a result of improvements in the perinatal care, the concept of *extended perinatal period* has been introduced. This period extends from 22nd week of gestation (or more than 500 g) to 7th day of life.

Perinatal Mortality Rate (PMR)

It is defined as late fetal plus early neonatal (first week) deaths of babies weighing more than 1000 g at birth (or 28th weeks of gestation or more) per 1000 total births weighing over 1000 g. It is suggested that for international comparisons, the numerator as well as the denominator in perinatal-neonatal statistics should be restricted to fetuses and infants weighing 1000 g or more.

$$\text{PMR} = \frac{\text{Total perinatal deaths}}{\text{Total number of births}} \times 100$$

$$\text{Extended PMR} = \frac{\text{Intermediate stillbirths} + \text{Late stillbirths} + \text{Early neonatal deaths}}{\text{Total number of births}} \times 100$$

The perinatal mortality rate within various birth weight groups and due to specific causes should be expressed. Population attributable risk of various adverse perinatal factors and idealized PMR by exclusion of non-salvageable causes of perinatal deaths should be calculated.

On the basis of NFHS-4 community-based studies, it is estimated that stillbirth rate in India is 9.7 per 1000 births. This rate is much lower than the modelled estimate of 22 per 1000 births by INAP.

Neonatal Period

Neonatal period extends up to 28 days of life. Infants up to 28 days of life are called newborns or neonates. Early neonatal period refers to first 7 days or under 168 hours of life while late neonatal period extends from 7 days to under 28 completed days of life.

Neonatal Deaths

First day deaths are defined as deaths occurring within 24 hours of age (exclude if baby had completed 24 hours of age). Early neonatal deaths include deaths within first week or <168 hours of age (exclude if baby has completed 168 hours of age). Neonatal deaths include all deaths within 28 days of age (exclude if baby has completed 28 days).

In case of premature babies, it would appear more logical to count 28 days of neonatal period from post-menstrual maturity of 40 weeks instead of date of birth. In any case, all neonatal deaths that occur before discharge from the NICU should be included in the statistics.

Neonatal Mortality Rate (NMR)

Early NMR Neonatal deaths of babies weighing over 1000 g during first 7 days per 1000 live births.

Late NMR or unspecified NMR Neonatal deaths of babies weighing over 1000 g during 28 days of life per 1000 live births.

The extended neonatal mortality rate can be calculated by including babies weighing up to 500 g. It is suggested that hospital-based neonatal–perinatal statistics may be presented separately for booked and unbooked cases.

The current NMR in India is around 22.7 per 1000 live births and it accounts for 70% of infant deaths (IMR 32) and 56% of under-5 child mortality (U5MR 42). NMR in rural areas is over one and a half times of the urban areas.

Birth Weight Classification for Perinatal–Neonatal Data

The morbidity and mortality can be expressed by weight intervals of 500 g, i.e. 1000–1499 g, 1500–1999 g, 2000–2499 g and so on.

Gestational Age Classification for Perinatal–Neonatal Data

Less than 28 weeks (less than 196 days)
28–31 weeks (196–223 days)
32–36 weeks (224–258 days)
37–41 weeks (259–293 days)
42 weeks and more (294 days and more)

Calculation of Incidence

The incidence of neonatal conditions (e.g. LBW babies, preterm, and birth asphyxia, etc.) should be calculated per 100 live births, while that of pregnancy and labor

related conditions (e.g. toxemia, maternal anemia, cesarean deliveries, etc.) should be calculated per 100 total births.

Maternal Mortality

The maternal death is defined as a death of a woman known to be pregnant within 42 days of termination of pregnancy, irrespective of the duration or site of the pregnancy. The death may be due to any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. The maternal mortality rate is expressed as maternal deaths per 100,000 live births. The current adjusted MMR in India is 122 per 100,000 live births accounting for 25% of global maternal deaths. The common correlates of high maternal mortality include poor socioeconomic status, unsatisfactory health and nutrition of women, illiteracy, early or delayed pregnancy, obesity, lack of antenatal care and delivery by untrained birth attendants.

Direct obstetric deaths Deaths resulting from complications of pregnancy, child birth or puerperium including interventions, omissions, incorrect treatment or from a chain of events resulting from any of the above causes. The common direct causes of maternal deaths include induced abortions, sepsis, hemorrhage, anemia, thrombosis and thromboembolism, amniotic fluid embolism, pre-eclampsia and eclampsia, ectopic pregnancy and obstructed labor.

Indirect obstetric deaths Deaths resulting from previous existing disease or a disease that developed during pregnancy, child birth or the puerperium which was not due to direct obstetric causes but which was aggravated by physiologic effects of pregnancy. The most common causes of indirect deaths include cardiac illnesses and psychiatric disorders.

CLINICOPATHOLOGICAL CLASSIFICATION OF PERINATAL DEATHS

There is a lack of unanimity and considerable confusion exists regarding the most acceptable method for classification of deaths during perinatal period. It is essential that all perinatal centers should adopt an identical or uniform protocol for clinicopathological classification of perinatal deaths so that mortality data is comparable in order to identify any regional differences. During perinatal period, many deaths cannot be classified merely on the basis of clinical findings unless it is complemented by autopsy data. Efforts should always be made to obtain an autopsy in each and every case of perinatal death. It is generally easier to obtain permission for autopsy in a case of perinatal death because of relatively less emotional bondage of parents and their concern for having a normal healthy baby during next pregnancy. A routine autopsy performed by an adult-oriented pathologist may not be informative and may be unable to identify the cause of death.

NEONATAL AUTOPSY

Identification of cause(s) of death, elucidation of pathogenetic mechanisms and assessment of quality of clinical management are the key objectives of autopsy examination at any age. Neonatal autopsy, in addition, is expected to guide the clinician to provide genetic counseling to the parents. Information derived from the stereotyped, adult-oriented, routine necropsies is very limited, and such a procedure is not cost-effective. Hence, a specially designed protocol should be developed for newborn autopsies at each center by the combined efforts of pediatricians and pathologists. Neonatal autopsy should be performed by a trained perinatal pathologist well-versed with its methodology. It is mandatory to accord due importance to anthropometry, assessment of gestation and recording of accurate weights of various body organs. Appropriate radiological, cytogenetic and metabolic studies should be undertaken, if dysmorphic features or congenital malformations are present.

Prerequisites for an Autopsy

Both maternal and neonatal case notes should be reviewed before commencing the postmortem examination. It is always helpful, whenever possible and in all complicated deaths, to discuss the case personally with the treating physician. This shall allow the pathologist to pay special attention to certain organs and plan appropriate additional investigations, like karyotyping, metabolic and microbiological studies.

The perinatal autopsy should commence after the pathologist has established from the available notes the maturity of the baby, birth weight, postnatal age (if live born) and probable cause and mode of death.

Anthropometry and Visceral Weights

The size of the baby and its organs varies with maturity and birth weight of the infant and these must be measured accurately and compared with known standards. It is often misleading to state that an organ is enlarged without taking into consideration these

facts. The organ weights may be affected in certain characteristic ways by malformation syndromes, placental insufficiency and diabetes mellitus.

Organ weights of each of the following internal organs should be independently and accurately taken; brain, heart, lungs, liver, spleen, thymus, kidneys and adrenals. The norms of standard weights of these organs at different gestations and birth weights should be available for ready reference (Tables 1.1 and 1.2). It is desirable to record weights of large organs to the nearest gram and that of smaller ones to the nearest 0.1 g by using an accurate weighing scale. Accuracy of weights of organs in neonatal autopsies is of great importance since some of the specific diagnoses, like hypoplasia of an organ, can be made only on the basis of weight.

In case of small-for-dates infants and babies born to diabetic mothers, it is important to compare the organ weights with that of normal appropriately grown infants of the same maturity. In small-for-dates babies, the brain appears to be relatively large while liver and thymus are atrophied. The weight of the heart and lungs is unaffected. The brain to liver ratio is usually more than 5 in growth retarded babies. In large-for-dates babies, all viscera weigh more than normal except the brain.

External Examination

The pathologist should do a thorough external examination, keeping in mind that there are a large number of syndromes with a typical phenotype. The general features, such as cyanosis, pallor, edema,

TABLE 1.1 Organ weights in grams by groups of body weights (mean ±SD)

Body weight (g)	*Brain*	*Heart*	*Lungs (combined)*	*Liver*	*Spleen*	*Adrenal glands (combined)*	*Kidneys (combined)*	*Thymus*
1000	143 ±34	7.7 ±2.0	24 ±8	47 ±12	2.6 ±1.5	3.5 ±1.6	10.4 ±3.4	3.7 ±2.0
1250	174 ±38	9.6 ±3.3	30 ±9	56 ±21	3.4 ±1.8	4.0 ±1.7	12.19 ±3.9	4.9 ±2.1
1500	219 ±52	11.5 ±3.3	34 ±11	65 ±18	4.3 ±2.0	4.5 ±1.8	14.9 ±4.2	6.1 ±2.7
1750	247 ±51	12.8 ±3.2	40 ±13	74 ±20	5.0 ±2.5	5.3 ±2.0	17.4 ±4.7	6.8 ±3.0
2000	281 ±56	14.9 ±4.2	33 ±13	82 ±23	6.0 ±2.7	5.3 ±2.0	18.8 ±5.0	7.9 ±3.4
2250	308 ±49	16.0 ±4.3	48 ±14	88 ±23	7.0 ±3.3	6.0 ±2.3	20.2 ±4.9	8.2 ±3.4
2500	339 ±50	17.7 ±4.2	48 ±15	105 ±21	8.5 ±3.5	7.1 ±2.8	22.6 ±5.5	8.3 ±4.4
2750	362 ±48	19.1 ±3.8	51 ±15	117 ±26	9.1 ±3.6	7.5 ±2.7	24.0 ±5.4	9.6 ±3.8
3000	380 ±55	20.7 ±5.3	53 ±13	127 ±30	10.1 ±3.3	8.3 ±2.9	24.7 ±5.3	10.2 ±4.3
3250	395 ±53	21.5 ±4.3	59 ±18	145 ±33	11.0 ±4.0	9.2 ±2.4	27.3 ±6.6	11.6 ±4.4
3500	411 ±55	22.8 ±5.9	6.3 ±17	153 ±33	11.3 ±3.6	9.8 ±3.5	28.0 ±6.5	12.8 ±5.1
3750	413 ±55	23.8 ±5.1	65 ±15	159 ±40	12.5 ±4.1	10.2 ±3.3	29.5 ±6.8	13.0 ±4.8
4000	420 ±62	25.8 ±5.1	67 ±20	180 ±39	14.1 ±4.0	10.8 ±3.4	30.2 ±6.2	11.4 ±3.2

Adapted from Gruenwald P, Minh HN. *Am J Clin Pathol* 1960, 34:247–253.

TABLE 1.2 Organ weights in grams by groups of gestational age (mean ±SD)

Gestation (weeks)	*Brain*	*Heart*	*Lungs (combined)*	*Liver*	*Spleen*	*Adrenal glands (combined)*	*Kidneys (combined)*	*Thymus*
28	139 ±48	7.6 ±2.3	23 ±7	46 ±16	2.6 ±1.4	3.7 ±1.7	10.4 ±3.6	3.8 ±2.1
30	166 ±55	9.3 ±3.3	28 ±11	53 ±19	3.4 ±2.0	4.2 ±2.2	12.3 ±3.9	4.6 ±2.3
32	209 ±44	11.0 ±3.7	34 ±11	65 ±22	4.1 ±2.1	4.3 ±2.3	14.5 ±4.8	5.5 ±2.3
34	246 ±58	13.4 ±3.9	40 ±13	74 ±27	5.2 ±2.1	5.5 ±2.3	17.7 ±5.3	7.5 ±3.8
36	288 ±62	15.1 ±4.8	46 ±16	87 ±33	6.7 ±3.0	6.4±3.0	21.6 ±6.7	8.1 ±4.2
38	349 ±56	18.5 ±5.5	53 ±15	111 ±40	8.8 ±4.2	8.4 ±3.5	23.8 ±7.0	9.7 ±4.8
40	362 ±55	20.4 ±5.3	56 ±15	130 ±45	10.0 ±3.9	8.6 ±3.4	25.6 ±6.5	9.5 ±4.4
42	405 ±54	21.9 ±6.2	56 ±18	139 ±45	10.2 ±4.3	9.1 ±4.0	25.8 ±7.5	10.4 ±4.4

Adapted from Gruenwald P, Minh HN. *Am J Clin Pathol* 1960, 34: 247–253.

jaundice and autolysis, should be looked for. Evidence of trauma in the form of bruises, punctures, forceps marks and incisions should be diligently searched for. All drainage tubes and catheters should be left *in situ* till the exact location of their tips is checked internally.

In a few centers, routine radiographs (whole body) are taken before each neonatal autopsy. They are of great help in the diagnosis of chondrodysplasias, osteogenesis imperfecta, intrauterine infections, meconium ileus, etc. In addition, they provide useful guidelines to assess the gestational age.

Thorax The thorax must be opened under water in a sink or a tub in all cases in order to detect pneumothorax especially in babies dying following resuscitation attempts and artificial ventilation. The presence of air can also be checked by aspirating the serosal cavities through a water-filled syringe before opening the chest and abdomen. It is useful to incise the heart under water, so that presence of air in the cardiac blood is revealed. Intracardiac air may be caused by air embolism following an exchange blood transfusion or by interstitial emphysema rupturing into the pulmonary vessel. Thoracic viscera are removed en bloc along with upper abdominal organs. Delineation of cogenital cardiac defects needs a systematic examination. If lungs appear solid, a piece of lung tissue should be dropped in a jar of water to see whether it floats or sinks. If it sinks, it is atelectatic (possible hyaline membrane disease), but if it floats in water, it is indicative of aerated lungs. Each lung should be weighed separately. If the weight is greater than +1SD, it is suggestive of pneumonia or massive pulmonary hemorrhage.

Umbilical vein, liver, stomach, pancreas and spleen should be removed in one block. The umbilical vein should be opened up to the liver and examined. The stomach and duodenum are dissected, and patency of bile passages confirmed by squeezing the gallbladder and observing for free flow of bile. If there is no flow of bile, biliary tracts should be dissected with precision.

The aorta is opened and umbilical arteries are examined for their number and distribution. If an umbilical artery catheter is *in situ*, position of its tip should be checked and thrombus looked for. Patency of renal arteries is checked. The adrenals are large in the newborn and may weigh up to half of the kidney. They regress in size during the first few days after birth. The congestion of the fetal zone may sometimes be mistaken for hemorrhage.

Head Newborn baby's head is very soft, and it deserves special treatment from the pathologist. Skull is opened by Beneke's technique avoiding damage to meninges and blood vessels. Before opening the vault of the skull, the contents of the posterior fossa should be examined by cutting down between the occipital bone and the atlas. Increased pressure of CSF can be recognized, if there is bulging of the meninges exposed through this gap, and blood or pus can be readily seen when the meninges are incised.

Each cerebral hemisphere may be removed separately cutting through the cerebral peduncles. Alternatively, the whole cerebrum can be removed by cutting through the midbrain, after freeing the anterior attachment of the falx, and then lifting the body till feet are over the head. The pons, medulla, and cerebellum may be removed after cutting through the tentorial leaflets and severing the cranial nerves and spinal cord.

After the brain has been weighed, it should be fixed in formalin for two or three weeks and then sectioned with a large knife. By placing the brain on its vertex, make cuts just in front of the temporal poles, in front of the midbrain, behind the midbrain, and in the occipital region. Hemorrhage should be identified and differentiated from choroid congestion. The pons, medulla and cerebellum are also incised. The definitive diagnosis of periventricular–intraventricular hemorrhage is made by cutting the brain after fixation.

Vertebrae and spinal cord Fracture or evidences of injury should be looked for. The state of vertebral vessels may be ascertained by histological section. In case of hydrocephalus associated with spina bifida, posterior cranial fossa and cervical spine should be examined for Arnold-Chiari malformation.

The Placenta

No fetal necropsy is complete until the placenta has been examined macroscopically and microscopically. Diseases of decidual vessels and extensive infarction may be an important cause of fetal death *in utero*. Inflammation of the placenta is always present in fetal pneumonia following prolonged rupture of membranes. The umbilical cord should be inspected for knots, ruptured vessels, number of umbilical arteries and their insertion. Placenta may be large in syphilis, hemolytic disease of the newborn while it is small in cases of placental insufficiency. Maternal surface of placenta should be looked for blood clots, infarcts, or malformations. Placenta should also be fixed for 2 to 3 weeks before sectioning. Four to five blocks of tissue

should be taken from the central slices and membranes for microscopic examination.

Histopathology

Histopathology of lung (one block from each lobe) is important because macroscopic diagnosis of pulmonary lesions is difficult. Hyaline membranes, which are pathognomonic of HMD, have been described as early as 3 hours of age. The diagnosis can be made in the presence of atelectasis with characteristic clinical course even in the absence of hyaline membranes. In the absence of recognizable macroscopic abnormality, sections of other organs seldom yield diagnostic information. Any tissue which appears abnormal should be examined microscopically. It should be remembered that postmortem preservation of fetal and neonatal tissues is far better compared to the adult tissues because of lower enzyme activities, more rapid cooling of body on refrigeration and less chances of bacterial proliferation.

Microbiological Studies

Blood culture should be obtained by collecting a sample from the heart under aseptic precautions. Blood may be obtained from the sagittal sinus through the anterior fontanel. The cultures must be routinely taken from the lungs.

Chromosomal Studies

Chromosomal analysis is indicated in the presence of facial dysmorphism, multiple malformations and dysmaturity. Sterile, anticoagulated blood prior to or at the time of death should be collected. Lymphocytes can be cultured up to 48 hours in such samples kept at room temperature. Tissues (skin, thymus, gonad) can be sent for karyotyping under special circumstances.

Biochemical Studies

Analysis of body fluids or frozen tissue or both for abnormal metabolites or enzymes is diagnostic in certain cases of otherwise unexplained neonatal deaths. Inborn error of metabolism should be suspected whenever unexplained neurologic, electrolyte or acid–base abnormalities are seen in an otherwise normal baby or if an earlier sib had died at an early age. Urine and serum samples should be lyophilized and sent for analysis to a well-equipped advanced biochemistry laboratory.

Final Diagnosis

The postmortem examination itself may not always give the information regarding the immediate cause of death. It is essential to correlate the gross autopsy, histological and microbiological findings with the clinical details of the mother and her infant to arrive at the primary cause and terminal event leading to death. Free and frank scientific interaction and discussion among pathologist, obstetrician and pediatrician in the form of a clinicopathological conference is an exceedingly useful exercise. The parents should be informed about the findings of autopsy by the consultant pediatrician and given an appropriate advise and guidance for future pregnancies.

For the purposes of classification of perinatal deaths, perinatal period is defined to include newborn babies dying within 7 days after birth and stillborn infants weighing 500 g or more, regardless of their gestational period. The following clinicopathological classification of perinatal deaths appears to be most comprehensive and should be followed. The cause of all perinatal deaths can be classified into the following four subgroups.

Primary Causes of Neonatal Deaths

They include major conditions which have directly or indirectly lead to the neonatal death. If there is more than one primary cause of death, they should be identified and the one which appeared to be the most significant in terms of lethality should be given priority. At times it may indeed be difficult to choose the cause of death among several primary causes of deaths in a given case. For example, if an infant with perinatal hypoxia develops aspiration syndrome at birth and subsequently dies from pneumonia, it may be difficult to identify the incriminating event which was actually responsible for death.

Extrinsic perinatal hypoxia It refers to perinatal hypoxia as evidenced by presence of features of fetal hypoxia and birth asphyxia (5-minute apgar score of ≤3) and occurs mostly due to complications of pregnancy or delivery. It excludes those conditions which cause intrinsic anoxia due to disorders in the infant, such as hyaline membrane disease, pneumonia PPHN, and cyanotic congenital heart disease. Pathologically, it is characterized by anoxic encephalopathy, congestion with or without focal petechial hemorrhages in the medulla of kidneys, adrenals, liver, and mucosa of gut. There may be evidences of massive amniotic fluid or meconium aspiration in the lungs.

Infections Sepsis is diagnosed on the basis of clinical, laboratory and pathological findings. Appropriate culture studies from blood and infected organs must be obtained at the time of autopsy to identify causative

microorganisms. Infected infants should be further subclassified into transplacental, intrapartum and postnatal depending upon timing of infection. Postnatal or nosocomial infection is diagnosed when infant is asymptomatic for at least 48 hours after birth and there is no evidence of intrapartum infection in the form of prolonged rupture of membranes, foul smelling liquor amnii, and polymorphs in the gastric aspirate of the neonate.

Hyaline membrane disease The diagnosis is based on characteristic predisposing factors, typical clinical and radiological picture and atelectasis with presence of diffuse hyaline membranes in the lungs. When it is associated with patent ductus arteriosus, intraventricular hemorrhage, subarachnoid hemorrhage, pneumonia or pneumothorax, bronchopulmonary dysplasia, the death is attributed to HMD.

Congenital malformations Those malformations which are severe enough and directly responsible for neonatal death are considered in this category.

Immaturity Immaturity as a cause of death is assigned to infants having birth weight of less than 750 g where no other primary cause of death is found on autopsy. These infants are grossly immature and are unable to maintain ventilation due to hyaline membrane disease, and die because of recurrent apneic attacks, intraventricular hemorrhage, and histologically their lungs are immature.

Miscellaneous causes Numerically less significant primary causes of neonatal deaths include erythroblastosis fetalis, necrotizing enterocolitis, massive primary pulmonary hemorrhage (in a relatively healthy infant), birth trauma (birth injury with fracture, massive subdural hematoma, visceral rupture), primary hemorrhagic disease of the newborn, and non-immunologic hydrops fetalis.

Cause unidentified Depending upon the experience of the neonatologist and pediatric pathologist and availability of investigative facilities, it may be difficult to assign a primary cause of death in about 10 to 20% of perinatal deaths. At times, stillborn baby may be so macerated that no meaningful information is obtained on autopsy.

Secondary Complications of Primary Disease

After identifying the primary cause of death, efforts should be made to identify the complications or terminal events which actually proved lethal. This is based on information regarding the mode of death and supportive pathological findings. The common complications during neonatal period which must be screened and specially looked for, both clinically and pathologically, include disseminated intravascular coagulation (secondary hemorrhagic disease of the newborn), intraventricular hemorrhage, patent ductus arteriosus, kernicterus, intestinal perforation, shock, sclerema, anemia, and metabolic complications.

Associated Fetal and Neonatal Conditions

The underlying fetal or neonatal conditions which may have accounted for development of primary disease and death should be identified. A large number of serious neonatal disorders are limited to immature infants, such as hyaline membrane disease, intraventricular–periventricular hemorrhage, nosocomial infections, and necrotizing enterocolitis. Infants with severe intrauterine growth retardation are predisposed to suffer from perinatal hypoxia, meconium aspiration syndrome, hypoglycemia, and pulmonary hemorrhage. Some non-lethal congenital malformations may be associated with life-threatening infections.

Associated Maternal Conditions or Complications of Pregnancy

They may account for primary cause of stillbirths in several cases. Infants of high-risk mothers are predisposed to develop several complications leading to increased morbidity and mortality. Those maternal conditions which are indirectly or directly responsible for unfavorable neonatal outcome must be identified so that strategies for reduction of perinatal mortality can be formulated in a proper perspective. The important maternal conditions or complications of pregnancy which must be specifically looked for in the antenatal case records including pregnancy-induced hypertension, essential hypertension, antepartum hemorrhage (placenta previa or abruptio placentae), chronic systemic disease, endocrinal disorders especially diabetes mellitus, nutritional status, drugs and infections during pregnancy, polyhdramnios or oligohydramnios.

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