

Anesthesia Care for the Premature Infant

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A 32-week-old baby girl presents for bilateral inguinal hernia repair. She was born at 26 weeks due to premature rupture of membranes. She had a patent ductus arteriosus (PDA) which was closed with indomethacin, as well as intubation for 1 week after birth for respiratory distress. She is currently extubated with a HR of 151, non-invasive blood pressure (NIBP) 51/33, with an O₂ sat of 95% on 2L nasal cannula (NC).

What Is a Preterm Infant? What Is a Term Baby?

A preterm infant is born between 20 weeks (viability) and 37 weeks of gestation. A term infant is born after 37 weeks of gestation. Classification is based on birth weight which can be correlated with morbidity and mortality (Table 7.1). Numerous issues are experienced by pre-term neonates affecting nearly every system (Table 7.2).

What Are the Unique Cardiovascular Issues in Preterm Infants?

Preterm infants generally have a higher total blood volume per kg than a term infant – approximately 110–120 mL/kg. However, their left ventricles are generally stiffer than term infants, and therefore very dependent on diastolic filling for generating cardiac output. As a result, very high heart rates may be deleterious as they impair diastolic filling due to shortening of the diastolic period. As such, they are less able to augment their cardiac output by increases in stroke volume when compared with older children and adults.

Patent ductus arteriosus, a highly prevalent issue in pre-term neonates, will be covered in Chapter 59.

What Is Bronchopulmonary Dysplasia?

Bronchopulmonary dysplasia (BPD) is a chronic lung disease as a result of prolonged mechanical ventilation

and high O₂ concentration exposure, and is more common in preterm infants (Figure 7.1). With better lung protection strategies in premature infants, specifically surfactant and steroid utilization, the severity of BPD has declined in recent years. These children also have increased airway reactivity throughout childhood.

How Is Pulmonary Hypertension Related to Prematurity?

Elevated pulmonary artery pressure is a major source of morbidity in the preterm infant. Failure of arborization or development of the pulmonary vasculature leads to elevated pressures. Severity of illness is directly proportional to the degree of prematurity. Vasculature development may improve as the child grows but is often abnormal.

What Is Apnea of Prematurity? Can It Be Prevented?

Apnea of prematurity is a form of centrally mediated apnea which decreases in incidence with rising post-menstrual age. In the NICU, generally physical stimulation or bag mask ventilation is used to resolve the apnea. Intravenous caffeine citrate reduces the incidence of apnea, however it has other side effects which have to be weighed against apnea reduction. This is discussed in greater detail in Chapter 18.

What Is Intraventricular Hemorrhage?

Intraventricular hemorrhage (IVH) has four grades of severity determined by the location of the hemorrhage. It is the most common form of neonatal hemorrhage and mainly occurs in preterm neonates, especially those <32 weeks of gestation.

Table 7.1 Gestational age and weight classifications

Gestational age	Birth weight	Classification
36–37 weeks	<2,500 grams	Low birth weight
31–36 weeks	<1,500 grams	Very low birth weight
24–30 weeks	<1,000 grams	Extremely low birth weight

Table 7.2 What are the most common problems faced by preterm infants?

Cardiovascular system	Patent ductus arteriosus, impaired ventricular diastolic filling
Respiratory system	Apnea of prematurity, bronchopulmonary dysplasia, pulmonary hypertension, laryngotracheal anomalies
Neurological system	Intraventricular hemorrhage, seizures, cerebral palsy
Integumentary system	Increased heat loss, decreased brown fat
Endocrine system	Hypoglycemia, decreased synthesis of vitamin K dependent factors
Hematopoietic system	Relative anemia, thrombocytopenia
Genitourinary system	Decreased tubular bicarbonate absorption
Gastrointestinal system	Necrotizing enterocolitis (NEC)
Ophthalmologic	Retinopathy of prematurity

What Is the Pathophysiology of Intraventricular Hemorrhage?

IVH in the preterm infant is multifactorial.

- The germinal matrix (present in children <35 weeks) is highly vascular and extremely susceptible to ischemia and hypoxic injury.
- Contributing factors may include:
 - Hypotension/reperfusion injury
 - Altered autoregulation in the neonate



Figure 7.1 Chest X-ray demonstrating severe bronchopulmonary dysplasia. Image by Pulmonological, reproduced under the CC BY-SA 3.0 license <https://creativecommons.org/licenses/by-sa/3.0/>.

- Susceptibility to hypervolemia (volume administration)
- Underdeveloped coagulation system
- Increased fibrinolytic activity in prematurity
- Poorly developed arteriovenous supporting structures

What Is Retinopathy of Prematurity and How Can Anesthesia Impact This?

The cause of retinopathy of prematurity (ROP) is multifactorial and is thought to be caused by vascular injury (due to hypoxia or hyperoxia, hypotension, etc.) and resulting free radical formation. As a result, there is angiogenesis and vessel development in abnormal areas (i.e., outside the retina). To prevent further hyperoxia induced damage, most NICU babies are maintained on the minimal tolerated oxygen concentration. During transportation, oxygen/air blenders should be used to avoid prolonged periods of hyperoxia. Intra-operatively, the minimal tolerated oxygen concentration should be used. Similarly, hypoxia should also be avoided.

What Is Cerebral Palsy?

Cerebral palsy is a clinical description of non-progressive injury to the developing brain. It is characterized by upper motor neuron lesions of various

Table 7.3 Grading of intraventricular hemorrhage in children by location and associated morbidity and mortality

IVH grade	Location of hemorrhage	Associated mortality (%)	Outcome	
			Progressive ventricular dilation (%)	Neurological sequelae (%)
Grade 1	Bleeding confined to periventricular area (around the germinal matrix)	5	5	5
Grade 2	Intraventricular bleeding <50% of ventricular area	10	20	15
Grade 3	Intraventricular bleeding >50% of ventricular area or resulting in ventricular enlargement	20	55	35
Grade 4	Intraparenchymal extension of bleed – Periventricular hemorrhagic/infarction	50	80	90

etiologies resulting in static encephalopathy. While the encephalopathy is static, progressive musculoskeletal pathology continues.

Cerebral palsy can be classified according to description of motor involvement and topography. Spastic and mixed motor disorders are far more common than dyskinetic cerebral palsy. Simultaneously, spastic hemiplegia, spastic diplegia, and spastic quadriplegia topographically characterize this condition. Those with spastic quadriplegia are more likely to develop scoliosis than those with either spastic hemiplegia or spastic diplegia. Scoliosis occurs secondarily due to failure of growth and ability to relax longitudinal skeletal muscle.

What Is the Incidence of Cerebral Palsy (CP)?

The incidence of CP is approximately 2–2.5/1,000 live births. The exact etiology of CP is unknown and it represents a collection of clinical symptoms rather than a single diagnosis. The causes are likely multifactorial and include antenatal factors, preterm delivery, intra-uterine infections, and inherited malformations.

What Are the Consequences of CP?

Progressive musculoskeletal disease often results in hip dislocation, and fixed contractures. Failure of growth of longitudinal muscles leads to contractures, long bone torsion, and joint instability. These musculoskeletal changes eventually lead to discomfort

related to degenerative joint changes. Other issues include gastroesophageal reflux and seizures.

Why Are Premature Neonates Prone to Hypothermia?

Preterm neonates have a decreased percentage of brown fat and thus, a decreased ability to generate heat by shivering thermogenesis. Since shivering is an important mechanism to maintain body temperature, this makes them more prone to hypothermia. Premature infants also have a large body surface area (BSA) which leads to evaporative heat loss. Therefore, careful attention must be paid to maintenance of body temperature in the operating room environment in these children.

Why Are Premature Neonates More Prone to Hypoglycemia? What Are the Risks of Hypoglycemia?

There are multiple etiologies for the premature infants' susceptibility to hypoglycemia. Briefly, the premature infant has increased use of glucose coupled with limited mechanisms of gluconeogenesis. This combination is potentially lethal due to the fragility of these small infants. Hypoglycemia is deleterious to the small infant because of their high dependence on glucose for basic metabolic functions. Therefore, in both NICU and operative environments, maintenance of glucose homeostasis is critical.

What Is Neonatal Acidosis?

A mild acidosis is common in neonates due to decreased renal tubular absorption of bicarbonate. This pushes the acid base curve toward increasing respiratory compensation for the acidosis. Under physiological conditions, the acidosis is limited and not harmful. However, under pathological conditions, the limited renal compensation puts even greater pressure on the respiratory component to compensate for acidosis. This explains the rapid acidosis and decompensation seen in ill premature infants.

What Is Necrotizing Enterocolitis?

Necrotizing enterocolitis (NEC) is a potentially fatal condition in which localized bacterial invasion of the intentional lumen leads to bowel perforation. Trans-luminal bowel perforation leads to spillage of bowel contents. There has been a shift toward medical management of NEC in preterm infants in recent years.

What Is the Preoperative Evaluation for the Premature Infant?

A systematic head to toe approach should be taken with all premature infants. Understanding the child's physiology, including temperature homeostasis, apnea and bradycardia episodes, and ventilatory impairments are important for the transport process and the operating room.

Pre- and post-ductal oxygen saturations should be employed when the ductus arteriosus is patent.

Line placement should be assessed.

Is Regional or General Anesthesia Preferred for This Procedure?

There is no uniform consensus answer to this question. The Vermont Infant Spinal Registry, which has the largest database of infant spinals in the country, has a high rate of long-standing success with the procedure in premature and term infants. Given that the spinal is done awake, however, this technique is limited to select centers that are comfortable with the procedure.

How Is a Neonatal Spinal Anesthetic Performed?

While many techniques including the use of the intercrystal line (Truffier's line) have been described,

other researchers typically utilize the most palpable interspace below the third lumbar vertebrae and to date have not recorded a conus puncture [personal correspondence, Robin Williams, MD, University of Vermont]. While both the sitting position and the lateral decubitus position have been described for block placement, the lateral decubitus position seems to offer the benefit of decreased risk of airway obstruction secondary to head flexion. On the other hand, it has been reported that palpation of bony landmarks seems to be easier in the sitting position. The distance from the skin to subarachnoid space has been calculated by ultrasound determination to be:

Distance from skin to subarachnoid space (cm)
= $0.03 \times \text{height (cm)}$

Distance from skin to subarachnoid space (cm)
= $(2 \times \text{weight}) + 7 \text{ (mm)}$

A dedicated person to act as "baby holder" is requisite for preventing movement, as well as to ensure neck extension during the placement of the spinal anesthetic. A variety of needles have been utilized for this purpose from 23 gauge to 26 gauge needles. There is no current data on the efficacy of the use of different needle gauges on block success. Once the block has been placed, it is important that the patient lies supine or even in a reverse Trendelenburg position to prevent cephalad spread, especially with hyperbaric solutions. Prompt attention to the airway is critical, including adequate head support and extension after lying the neonate supine. All local anesthetics have been successfully used for infant spinals, including 0.5–0.6 mg/kg tetracaine 0.5%, 1 mg/kg 0.5% isobaric bupivacaine or ropivacaine, and 1.2 mg/kg of isobaric 0.5% levobupivacaine.

The onset of analgesia is between two to four minutes.

Is the Incidence of Postoperative Apnea Different Between Regional and General Anesthesia?

Multiple studies have looked at the incidence of regional anesthesia versus general anesthesia and are inconclusive. There are significant confounders in this vulnerable population and therefore, further studies are needed to clarify this issue. Post-operative apnea is discussed in greater detail in chapter 18.

Suggested Reading

- Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy. *Dev Med Child Neurol.* 2005;47(8):571–6. PMID: 16108461.
- Davidson AJ, Morton NS, Arnup SJ, et al. Apnea after awake regional and general anesthesia in infants. *Anesthesiology.* 2015;123(1):55–65. PMID: 26001028.
- Kidokoro H, Andersen PJ, Doyle LW, et al. Brain injury and altered brain growth in preterm infants: predictors and prognosis. *Pediatrics.* 2014;134(2):e444–53. PMID: 25070300.
- Taneja B, Srivastava V, Saxena K. Physiological and anesthetic considerations for the preterm neonate undergoing surgery. *J Neonatal Surg.* 2012;1(1):14. PMID: 26023373.