Chapter 68
The Neonatal Surgical Patient

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Abstract It is universally agreed that the child is not a small adult in terms of physiology, pathophysiology, pathology and response to surgical stress. Similarly, the neonate is not a small child. The neonate represents a unique surgical patient with specific characteristics depending on its immaturity, also due to preterm birth in some cases, and the type of disorders, usually congenital and complex. In this chapter, we introduce the characteristics the surgical neonate and will discuss the general aspects of its management.

Keywords Neonatal nutrition · Pain management · Perioperative antibiotic prophylaxis · Surgical neonate

1. **How can neonates be classified according to their level of maturation (gestational age) and development (weight)?**

A term, appropriate for gestational age infant is one born between 37 and 42 weeks of gestation with a birth weight greater than 2.500 gr (Table 68.1). Maturation and development are crucial factors influencing the infant outcome (Table 68.2).

2. **What are the features of small for gestational age (SGA) newborns?**

Newborns whose birth weight is below the 10th percentile are defined SGA. Placental, maternal, and/or fetal abnormalities may cause restricted intrauterine

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Table 68.1 Newborn classification by maturation and development (gestational age)

By maturation	Age at birth
Preterm	Before 37-week gestation period
Term	Between 37- and 42-week gestation period
Post-term	After 42-week gestation period
By development	**Birth weight**
Small for gestational age (SGA)	Below 10th percentile
Appropriate for gestational age	Between 10 and 98th percentile
Large for gestational age	Greater than 98th percentile

Table 68.2 Newborn clinical classification by birth weight

Classification	Birth weight (g)	% preterm births	Mortality versus term
Moderately low	2500–1501	82	×40
Very low	1500–1001	12	×200
Extremely low	<1000	6	×600

Table 68.3 Common conditions associated with intrauterine growth retardation

Age at delivery	Condition
Preterm	Placental insufficiency, discordant twinning, chronic maternal hypertension, intrauterine infection, toxemia
Term	Congenital anomalies, microcephaly
Post-term	Placental insufficiency

growth (Table 68.3). It is important to differentiate infants born small as a result of factors such as ethnicity, sex, and geography from those whose relatively low birth weight is a result of genetic or intrauterine abnormality.

3. **What are the physiological and anatomical factors that make the preterm infant vulnerable and what are the sequelae?**

   – Central nervous system immaturity: apnea, bradycardia, weak sucking reflex, increased risk of brain hemorrhage.
   – Pulmonary immaturity: surfactant deficiency, hyaline membrane disease, respiratory distress at birth.
   – Vascular immaturity and fragility: increased risk of intraventricular hemorrhage and retinopathy of prematurity.
   – Skin immaturity: underdeveloped stratum corneum with significant transepithelial water loss and complicated thermal regulation and fluid status management.
   – Gastrointestinal immaturity: inadequate absorption and risk of necrotizing enterocolitis.
   – Cardiovascular immaturity with patent ductus arteriosus or patent foramen ovale: potential persistent left-to-right shunting and cardiac failure.

4. **What are the differences between associations, syndromes and sequences?**

Associations are groups of malformations occurring together more often than expected by chance, and do not have evidence of a single unifying cause. Syndromes have more than one phenotypic feature and consist of malformations that occur together more than expected by chance, with a single unifying or presumed cause. Sequence is a consequence, result, or subsequent development of a disease (e.g. Pierre-Robin sequence: micrognatia causes glossoptosis that causes cleft palate).

Associations, syndromes and sequences are frequent in surgical neonates with a congenital anomaly. Therefore, a systematic screening of all organs and systems is required.

5. **How can fluid and electrolytes requirement be calculated in the newborn baby (Table 68.4)?**

a. The basic maintenance requirement is the volume required to support growth and replace losses from renal excretion (renal water), skin, lungs, and stool. Invisible continuing water loss occurs from the lungs (respiratory water loss) and skin (transepithelial water loss) and constitutes insensible water loss (IWL). The insensible water loss for a full-term infant in a thermoneutral environment at 50% humidity is approximately 12 mL/kg per 24 hours (33% respiratory, 50% transepithelial).
b. Dextrose infusion to maintain appropriate blood glucose levels. The fetus has limited capacity of gluconeogenesis and limited liver glycogen stores, rapidly depleted within 2 to 3 hours after birth. Also, the neonate has limited ability to synthesize glucose from fat or protein substrates.
c. Electrolytes added in amounts to appropriately maintain homeostasis. Basic electrolyte and energy requirements are provided by NaCl (2–5 mEq/kg/day) with addition of potassium (2–3 mEq/kg/day) once urine production has been established. Calcium gluconate (1–2 g/L fluid) may be added, especially in preterm infants [1].

Table 68.4 Maintenance fluid requirements of neonates, usually as 10% dextrose (mL/kg/day)

Birth weight (g)	1–2 days of age (ml)	3–7 days of age (ml)	7–30 days of age (ml)
<750	100–250	150–300	120–180
750–1000	80–150	100–150	120–180
1000–1500	60–100	100–150	120–180
1500–2500	60–80	100–150	120–180
>2500	60–80	100–150	120–180

6. **What are the metabolic requirements for the surgical neonate?**

In the neonate, energy requirements are higher (higher growth rate and lower energy reserves). For enterally fed infants, the total energy requirement is 100–120 kcal/kg/day in term infants and 110–160 kcal/kg/day in preterm infants. In infants receiving total parenteral nutrition (TPN), energy requirements are slightly lower (80–100 kcal/kg/day), due to reduced energy losses. The neonate does not seem to have a significant metabolic response to surgery [2].

7. **Which are the nutritive options in the surgical neonate?**

Feeding should be through the enteral route whenever possible (less infectious risks, better immune response and entero-hepatic circulation of bile acids). Breast milk is the first choice as it contains several antimicrobial factors, antioxidant molecules and growth factors. If breast milk is not available or in case of nutrition through a jejunal tube, formulas tailored to the specific needs are available. Milk contains approximately 70 kcal every 100 ml. If enteral nutrition is not possible or contraindicated, and if fasting is predicted to last longer than 7 days, TPN should be provided (Table 68.5). If a central venous line cannot be obtained, peripheral PN with lower osmolarity (maximum 10–12.5% dextrose) and shorter duration (<2 weeks) can be provided. In addition to carbohydrates, lipides and aminoacids, TPN should contain electrolytes, minerals, vitamins, trace elements, and water. For vitamins and micronutrients, we suggest referring to specific NASPGHAN guidelines [3]. During PN, electrolytes, urea and creatinine, liver function tests, triglyceride levels, and trace elements should be monitored (once a week).

8. **When does a surgical neonate require central venous access?**

Central venous access is required for long-lasting therapies with hypertonic or irritating solutions, repeated blood sampling and invasive hemodynamic monitoring. Central venous access may be obtained shortly after birth through the umbilical vein (UV) (lasts less than 7 days), using peripherally inserted central lines (although only very thin catheters can be inserted and have a limited life: 30 days), or can be placed under ultrasound guidance or direct vision surgical venotomy in the internal jugular, the subclavian or the femoral vein. These last longer and may be larger and allow to draw blood, that is usually not possible with tiny peripherally inserted catheters.

Table 68.5 TPN components in neonates

TPN component	Purpose	Initial (g/kg/day)	Increase rate (g/kg/day)	Maximum (g/kg/day)
Carbohydrates	Energy (4 kcal/g)	7–8	1.5–4	17–22
Lipids	Energy (9 kcal/g)	1–2	0.5–1	3
Aminoacids	Protein turnover and tissue growth	2–3	1	3–4

9. **What are the risks related to central venous catheters?**

Short-term:
- Malfunction/displacement
- Infection
- Perforation and development of accidental hemorrhage
- Hemopericardium
- Cardiac arrythmias (if in the right atrium)
- Air embolus. In a spontaneously breathing baby, never open a catheter to the air (if the tip is above the diaphragm for UV catheters).

Long-term:
- Malfunction/displacement
- Infection
- Embolization and infarcts
- Thrombosis of hepatic vein (UV catheters)
- Liver necrosis (UV catheters)

10. **What are the goals of appropriate preoperative care [4]?**

a. Identifying, optimizing and managing coexisting clinical conditions
- Preoperative evaluations performed by the anesthesia team
- Full review of all systems

b. Preparing the patient for the specific operation: Informed consent

Except in the rare case where surgical intervention is necessary to prevent imminent death, informed consent in neonates requiring surgery mandates effective preoperative family education and counseling. Informed consent should disclose at least the following information:

- Surgeon understanding of the problem;
- Further measures to be taken to clarify the diagnosis, if indicated;
- Indication for emergency operation;
- Brief description of the procedure;
- Alternatives to treatment, including the option of doing nothing;
- Surgeon recommendation as to the best alternative;
- Benefits and risks of the proposed operation, compared with alternatives;
- Anticipated outcome

c. Preparing the family for the perioperative period.

11. **What are the aims of preoperative anesthesia assessment?**

- To obtain the clinical information for conducing the anesthesia
- To decide which examinations are indicated
- To give the risk assessment
- To obtain parents' informed consent
- To prescribe preoperative fasting
- To decide which anesthetic technique is best tailored to the patient's needs.

12. **Do surgical neonates need routine laboratory or instrumental testing?**

Infants scheduled for minor surgery, with silent medical history and/or negative physical examination, do not need particular pre-operative tests. In neonates undergoing major surgeries, preoperative tests are indicated, based on patient history and clinical examination performed during the preoperative evaluation.

13. **What is the definition and treatment of anemia in neonates?**

Anemia is a reduction of hemoglobin levels (or hematocrit) below 2SD normal values. Causes of anemia include reduced red blood cells production, increased destruction, and blood losses. Anemia may present with a variety of clinical manifestations including pallor, tachycardia, tachypnea or apnea, lethargy, poor feeding, increased oxygen requirements, poor growth, jaundice, and metabolic acidosis. As red blood cell transfusions are not exempt from risks, they should be limited to neonates with severe clinical manifestations. The majority of red blood cell transfusions to neonates are top-up transfusions of small volumes, typically 10–20 ml/kg over 4 hours (Table 68.6).

14. **What are the pre-operative fasting times in a surgical neonate?**

Two hours for clear liquids, four hours for breast milk, and 6 hours for infant formula.

15. **Why is gastric decompression in neonates undergoing surgery important** [4]**?**

Gastric distension carries the risk of regurgitation, aspiration and pneumonia, and may impair diaphragmatic excursion, with respiratory distress. In patients where ventilation is impaired for intestinal distention (intestinal atresia, congenital diaphragmatic hernia), or where intestinal distension impedes reduction of herniated intestine into the abdominal cavity (abdominal wall defects), gastric and intestinal distention may be prevented and/or alleviated by adequate orogastric decompression.

Tips for gastric decompression:

- Check the correct tube position in the stomach measuring the tube before insertion, noting the nature of the aspirate, and radiography (when required).
- Carefully tape the tube to avoid displacement.
- Use low continuous suction. If a single-lumen tube is used, intermittent aspiration is required.
- Use of gastrostomy tubes for postoperative gastric decompression may be considered, if present.

Table 68.6 Suggested transfusion thresholds

Gestational age (postnatal age)	Ventilated/cyanotic	Stable/off oxygen
<37 weeks (1st week)	12 g/dl	10 g/dl
<37 weeks (2nd week on)	10 g/dl	8 g/dl
>37 weeks	10 g/dl	7 g/dl

16. **What is the optimal temperature in a surgical neonate and how can it be maintained** [4]**?**

Neonates are susceptible to heat loss and have poor heat production competence. Hypothermia may increase the risk of intra-operative and post-operative complications, such as acidosis, bleeding, impaired immune function and delayed wound healing. Environmental temperature must be maintained near the thermoneutral zone appropriate for age: 32 °C-34°C in term infants, and 34 °C-35°C in low-birth-weight infants.

- The neonate environmental temperature is best controlled in an incubator
- Covering the head with an insulated hat can reduce heat loss (reducing cold stress by up to 15%)
- Use of insulating padding. Incubators themselves are plastic-walled containers that warm the infant by convection. Humidity can also be provided to the incubator environment, reducing evaporative heat loss.
- Radiant warmers provide open access to and visibility of infants who require frequent manipulation. However, they do not prevent heat loss by convection and often lead to higher evaporative water and heat losses. This evaporative heat loss may be reduced by plastic sheets.

In the operating room or radiology suite heat loss may be reduced by:

- Wrapping the head, extremities, and as much of the trunk as possible in clothing, plastic sheets, or aluminum foil.
- A plastic sheet beneath the infant may decrease humidity of the microenvironment
- Exposed intestine should be wrapped in plastic/warm gauzes.
- A heater system should be used during induction of anesthesia, preparation for operation, and at the termination of the operation.
- Solutions used for skin cleansing as well as intracorporeal irrigation should be warmed.

17. **Where should we operate on the preterm neonate?**

Disadvantages of surgery in the NICU.

- Unfamiliarity with the NICU environment. This entails ensuring that there is reliable availability of the necessary equipment, instruments, and disposables that surgeons and anesthesiologists will require.
- Restricted workable space for the surgical team, potentially limiting the ability to give quality care to the infant.
- Specific training to anesthesiologists on the NICU ventilators so that necessary adjustments can be made promptly as the patient's condition requires.

Benefits of surgery in the NICU.

- Infants can continue to receive their ongoing intensive care with minimal disruption and immediate return to the care of medical and nursing staff, once the procedure is completed.
- No exposure to the inherent risks of transport

– NICU surgery should be avoided where necessary bulky or overtly impractical ancillary equipment is necessary (intraoperative diagnostic imaging, laparoscopic, thoracoscopic, and endoscopic procedures, or where particular patient positioning is required). By contrast, some patients are currently operated on in the NICU: operations on ECMO, exploration and closure of postoperative sternotomies, ligation of PDAs and particularly ligation or partial occlusion of arterio-pulmonary shunts on extracorporeal circuits, need for high-frequency oscillatory ventilation.

18. **Describe antibiotic prophylaxis in the surgical neonate.**

In the surgical neonate, post-operative infectious complications contribute significantly to morbidity and mortality. Perioperative antibiotic prophylaxis (PAP) may reduce this burden. Appropriate antibiotic prophylaxis should cover the potential pathogens while reducing the risk of development of antibiotic resistant organisms. PAP is defined based on the type of surgery: **clean, clean-contaminated**, **contaminated** [5]. PAP is begun at anesthesia induction.

In Table 68.7 our Hospital's PAP.

Table 68.7 Antibiotic prophylaxis in neonatal surgery

Clean	**Prophylaxis**	
CVC/Broviac/Port	None	
Bronchoscopy		
Circumcision		
Inguinal hernia		
Neonatal testicular torsion		
Ovarian cyst		
Clean-contaminated		
Biliary tract/choledochal cyst	Cefazolin	1 dose
Congenital diaphragmatic hernia		
Gastroschisis/omphalocele		
Duodenal atresia		
Gastrostomy tube		
Nissen fundoplication		
Liver biopsy		
Head and neck surgery		
Contaminated		
Lung surgery	Cefazolin (lung/upper GI)	48–72 h
Esophageal atresia/	Cefoxitin + Gentamycin (lower GI)	
tracheo-esophageal fistula		
Jejunal/ileal atresia		
Hirschsprung disease pullthrough		
Ostomy closure		
Anorectoplasty		

19. **Which are the most common general post-operative complications in the neonate?**

Neonates have a unique response to surgery and may develop complications unrelated to the type of surgery they underwent. The newborn, especially if preterm, is particularly sensitive to pain and stress. Uncontrolled pain and stress may result in several adverse responses in circulatory, metabolic, immunologic, and hematic systems. In addition, the neurologically immature brain is most susceptible to long-term developmental effects. The immature central nervous system of the newborn is particularly susceptible to post-operative respiratory problems, predisposing to apnea, and is prone to depression following general anesthesia and administration of analgesics or sedatives. Moreover, residual effect of neuromuscular blocking agents may cause post-operative respiratory compromise. As a consequence, neonates need post-operative continuous monitoring of heart rate, respiration and oxygen saturation.

20. **What pharmacological post-operative pain management is available for the surgical neonate?**

Opioids provide the most effective therapy for moderate to severe pain. They produce both analgesia and sedation, have a wide therapeutic window, and attenuate the physiologic responses to stress. Among opioids, morphine and fentanyl are the most commonly used.

Paracetamol is frequently used in conjunction with other analgesics to decrease opioid use. Its main toxicity is liver damage; however, when given in appropriate doses, it is safe and effective.

Surgical stress response may also be effectively mitigated by regional anesthesia such as subarachnoid block (little use in neonates), lumbar/thoracic epidural analgesia, peripheral blocks, associated with a low risk of complications and a reduced need for intraoperative and post-operative opioid analgesics. Figure 68.1 shows a tiered approach to neonatal pain [6].

21. **How is post-operative pain assessed in a surgical neonate?**

In neonates, the management of pain must rely on behavioral and physiological markers.

Behavioral indicators: crying, facial activity, body language, complex behavioral responses. Physiological indicators: changes in heart and respiratory rate, blood pressure, oxygen saturation, vagal tone, palmar sweating, and plasma cortisol or catecholamine levels.

Currently the most used pain-assessment tools are:

- PIPP (Premature Infant Pain Profile), used in a gestational age of 28–40 weeks for procedural and postoperative pain;
- CRIES (Crying, Requires Oxygen Saturation, Increased Vital Signs, Expression, Sleeplessness), used in a gestational age of 32–36 weeks for postoperative pain;
- NIPS (Neonatal Infant Pain Scale), used in a gestational age of 28–38 weeks for procedural pain.

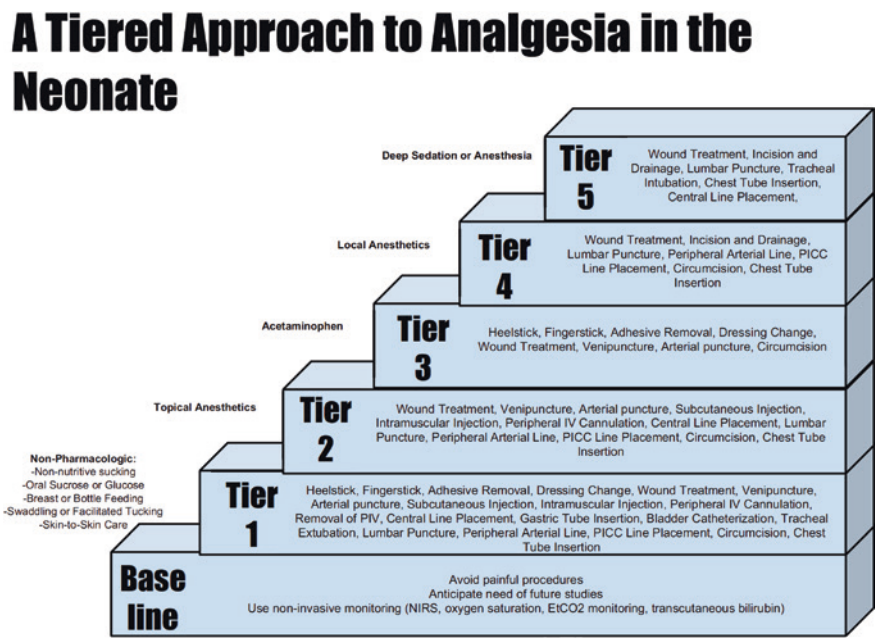

Fig. 68.1 A tiered approach to neonatal pain (from Witt N, Coynor S, Edwards C. et al. Curr Emerg Hosp Med Rep. 2016;4:1–10)

22. **What is the post-operative time to resume enteral feeding?**

It depends on the disease leading to the operation and the surgical procedure. In general, after a surgical procedure not involving the digestive system and in case of an operation not causing a postoperative ileus, the rule is two hours for clear liquids and three hours for milk and solid food. In case of abdominal surgery, small-volume feeding may be resumed when gastric aspirate or drainage is below 20 ml/kg/day and there is evidence of bowel function and should be increased gradually (1–2 ml/hour/day). Tolerance should be assessed controlling the amount of gastric aspirate/residual, the stoma/stool output, and abdominal girth.

References

1. D'Haringue AE, Byrne WJ. Nutrition in the newborn. In: Schaffer and Avery's Diseases of the Newborn, pp. 709–725. HW Taeusch, et al. Eeds. W.B. Saunders, Philadelphia, USA, 1991
2. Pierro A, Eaton S. Metabolism and nutrition in the surgical neonate. Semi Pediatr Surg. 2008;17:276–84.
3. https://www.naspghan.org/files/documents/pdfs/Parenteral%20Nutrition%20Slide%20Set.pdf.

4. Bruzoni M, Albanese CT. Perioperative Management of the Neonatal Patient. In: Surgical Care of Major Newborn Malformations, pp 1–32. Dolgin SE, Hamner CE Eds. World Scientific Publishing Co. Pte. Ltd. Singapore, 2012
5. National Collaborating Centre for Women's and Children's Health (UK). Surgical Site Infection: Prevention and Treatment of Surgical Site Infection. London: RCOG Press; 2008 Oct. (NICE Clinical Guidelines, No. 74.) Available from: https://www.ncbi.nlm.nih.gov/books/NBK53731/
6. Witt N, Coynor S, Edwards C, et al. A Guide to pain assessment and management in the neonate. Curr Emerg Hosp Med Rep. 2016;4:1–10.