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Chapter 1

Perioperative Care of the Neonate

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Additional information is available at the end of the chapter

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Abstract

Care of the perioperative neonate requires careful consideration of many aspects including the impact of anesthesia and surgery on multiple organ systems. Neonatal care should include close attention to achieving homeostasis and stability in the perioperative period. This chapter will address the critical elements in the management of the surgical neonate.

Keywords: neonate, surgical care, Neonatal Intensive Care Unit (NICU)

1. Preoperative care of the neonate

Care of the preoperative surgical neonate starts with a comprehensive history and physical examination on admission. It is important to focus on airway, respiratory, cardiac, and renal abnormalities which may impact surgery. Preoperative lab studies should include a complete blood count with differential, basic metabolic panel, coagulation studies and cross match blood screening [1, 2].

Preoperative airway management includes consideration of need for intubation and mechanical ventilation and chest radiography to confirm endotracheal tube position, to assess lung volumes and to evaluate cardiomegaly. Endotracheal intubation is often completed by the neonatal intensive care physician though at times pediatric anesthesia may prefer this responsibility; therefore, communication is important.

Additional preoperative goals include optimizing ventilation and oxygenation, correcting abnormal electrolytes and pH and ensuring adequate perfusion. Lab work should forewarn clinicians of anemia and thrombocytopenia which should be corrected with goal neonatal hematocrit of 30–35% and platelet count greater than 100,000 preoperatively. Coagulation studies should be normalized with fresh frozen plasma and cryoprecipitate as needed prior to

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surgery. In cases of liver dysfunction, consider vitamin K administration. Disseminated intravascular coagulation should be considered and treated if sepsis is suspected. Ideally, surgery should be deferred if sepsis is suspected.

Adequate intravenous access is necessary prior to surgery. The need for central venous line placement should be determined and discussed with the anesthesiologist and pediatric surgeon in advance. If percutaneous central venous line placement is unsuccessful, central venous line may need to be placed by surgery. Factors that should be weighed in determining the need for central line placement include type of surgery, anticipated recovery time and anticipated length of time to regain bowel function. If the neonate is expected not to tolerate adequate enteral volumes for appropriate nutrition or to be nil per os (NPO) for greater than 2 – 5 days, then central line access should be considered [3].

Length of NPO status should be discussed with the surgeon. For elective procedures requiring anesthesia or sedation, the American Society of Anesthesiologists recommends neonates be NPO for at least 4 hours if fed breast milk and 6 hours if fed formula prior to surgery [4]. NPO status is at times outweighed by the need for emergency surgery in cases of critical illness.

Choice of intravenous fluid replacement is in large part dictated by the disease process, surgery and type of therapy anticipated [5]. Intravenous fluids should include provision for maintenance fluids and, if indicated, fluid and electrolyte replacement to correct deficits and for surgical conditions with anticipated fluid loss (see **Table 1**). Neonates are born with excess total body water in comparison with muscle mass and fat. The more preterm neonates have increased extracellular fluid. After birth, there is a shift of fluid from the extracellular compartment that results in salt and water diuresis by 48 to 72 hours and physiological weight loss in the first week of life. Failure to have adequate diuresis is associated with increased morbidities including pulmonary edema, tissue edema, symptomatic patent ductus arteriosus, necrotizing enterocolitis (NEC) and chronic lung disease [5–8]. Neonates are more sensitive to hypovolemia due to relatively low cardiac contractility. Maintenance fluid replacement should allow for the initial loss of extracellular fluid diuresis over the first week of life while maintaining normal intravascular volume and tonicity reflected by heart rate, urine output, electrolytes and acid/base status [5].

Birth weight (g)	Insensible water loss (mL/kg/day)	Total water requirement by age (mL/kg/day)		
		Day 1–2	Day 3–7	Day 8–30
<750	100+	100–200	120–200	120–180
750–1000	60–70	80–150	100–150	120–180
1001–1500	30–65	60–100	80–150	120–180
>1500	15–30	60–80	100–150	120–180

Adapted from Ref. [45].

Table 1. Maintenance fluid requirements during the first month of life [5].

Careful estimation of ongoing pathogenic fluid losses is important to determine the best volume and composition of fluid replacement. Estimation of fluid and electrolyte losses can be difficult especially in conditions that predispose to third spacing such as sepsis, hypoalbuminemia, intra-abdominal infection, postoperative abdominal surgery or cardiac surgery. Calculating daily gross intake and output along with serial weight can help to estimate fluid loss. Electrolyte losses can be estimated by multiplying the volume of fluid loss by the electrolyte content of the type of body fluid (see **Table 2**) [5].

Fluid source	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)
Stomach	20–80	5–20	100–150
Small intestine	100–140	5–15	90–120
Bile	120–140	5–15	90–120
Ileostomy	45–135	3–15	20–120
Diarrheal stool	10–90	10–80	10–110

Adapted from Ref. [45].

Table 2. Electrolyte content of body fluids [5].

Normal saline boluses of 10–20 mL/kg should be given to maintain adequate renal perfusion to ensure normal urine output (2–3 mL/kg/hour). Fluid should also be given to maintain normal blood pressure based on gestational age. Caution should be used when administering greater than 40 mL/kg of fluid boluses to support blood pressure as this should prompt evaluation regarding the cause of hypotension. Fluid boluses must be balanced by the risk of patent ductus arteriosus in at-risk preterm neonates. Need to increase total fluid intake may be better tolerated by gradually increasing overall total daily fluid rate rather than by giving fluid boluses. Metabolic acidosis can be buffered by the administration of sodium acetate in fluids given to maintain central line patency. Hypoproteinemia should be corrected slowly if possible preoperatively to ensure better postoperative wound healing. An early assessment of serum albumin should be considered, as this may be reflective of prognosis for severity of gastroschisis. In most instances, administration of albumin for fluid replacement and to correct hypoalbuminemia should be discouraged as the albumin leaks into the tissues and contributes to tissue edema. Consideration should be given to placement of a Foley catheter for very long procedures or very unstable or chemically paralyzed neonates. Perfusion should be monitored and normalized. Assessment of tissue perfusion includes measuring blood pressure by peripheral cuff or by arterial line placement. Monitoring arterial blood pressure by indwelling arterial line is indicated for critically ill neonates if a period of postoperative instability is expected, if the neonate is requiring vasopressors or for frequent blood sampling.

Significant morbidity and mortality of perioperative neonates are related to hypoxic/ischemic events. Most intensive care units monitor perfusion index as part of skin surface oxygen saturation monitoring [9, 10]. More institutions are using near infrared spectroscopy (NIRS) to assess tissue perfusion. While pulse oximetry provides a measure of arterial oxygen

saturation, it may not be particularly useful for determining oxygen delivery to the tissues. NIRS regional oximetry measures the balance between local oxygen delivery and consumption beneath the sensor. NIRS provides an end-organ measure of not only oxygenation, but also perfusion. NIRS can be used as a continuous, real-time, noninvasive bedside monitor using infrared light sensors of regional tissue oxygenation and hemodynamics [11]. It is United States Food and Drug Administration (FDA) approved for use in neonates, including those less than 2.5 kg. Regional tissue oxygen saturation reflects a ratio of arterial and venous blood (25:75%) and the balance between oxygen delivery and tissue consumption. NIRS monitoring usually includes measuring cerebral and somatic, either renal or mesenteric, regional oxygen saturation. There are norms of average NIRS values for cerebral, renal and mesenteric areas of monitoring, providing a noninvasive measure of end-organ oxygenation and perfusion [12]. These norms vary between term and preterm neonates (see **Table 3**).

rSO2	Term	Preterm
Cerebral (%)	66–89	66–83
Renal (%)	75–97	64–87
Mesenteric (%)	63–87	32–66

Values differ by sensor type with neonatal sensors reading 10% higher. Adapted from Refs. [13, 14].

Table 3. Normal ranges of regional oxygen saturation (rSO2) in term [13] and preterm [14] neonates.

Gastric decompression by Replogle sump tube should be discussed with surgeon and must be considered for neonates with intestinal obstruction. Cases to strongly consider gastric decompression include surgical necrotizing enterocolitis, Hirschsprung's disease, intestinal atresias, gastroschisis and omphalocele.

Preoperative labs should be obtained within 24 hours of planned surgery to ensure infection is ruled out. Prophylactic antibiotics should be given within 1 hour of skin entry [1]. At some hospitals, this timing is best achieved if antibiotic such as cefazolin is given in the preoperative surgical area as part of a preoperative checklist. Antibiotic choice should be dependent on disease process. Suspected perforation should be treated with broad-spectrum antibiotics that specifically include Gram-negative and anaerobic coverage. Length of therapy and choice of antibiotics may change depending on the intraoperative findings and culture results.

2. Common conditions of the surgical neonate

Although various conditions require specific management, the initial management of the surgical neonate consists of gastric decompression with placement of a Replogle tube, imaging including abdominal radiographs, and fluid and electrolyte management. The use of antibiotics is dependent upon the suspected pathology. Specialized management considerations are reviewed for the following conditions.

2.1. Gastroschisis

Gastroschisis is a congenital anterior abdominal wall defect that occurs to the right of the umbilical cord insertion that results in herniation of abdominal contents and thereby permitting bowel exposure to amniotic fluid in utero [15]. Abdominal contents generally contain the small intestine; however, larger defects may contain the stomach and colon [16]. Compared to an omphalocele defect, there is no transparent sac to protect the intestine and gastroschisis is not usually associated with other congenital syndromes. However, it may be associated with other gastrointestinal abnormalities such as malrotation, atresia or stenosis. A neonate with a prenatal diagnosis of gastroschisis should preferably be delivered at an institution with multidisciplinary care, influx into maternal-fetal medicine service, neonatal intensive care team and pediatric surgery. At the time of delivery, the neonate should be placed in a bowel bag enclosed to the neonate's axilla. This bag protects the bowel and also helps to retain body heat. Given the location of the defect, the neonate should be placed right side down to avoid tension on the mesenteric vasculature. A Replogle tube should be placed at the time of delivery to allow for abdominal decompression. All neonates should receive empiric broad-spectrum antibiotics, preferably ampicillin and gentamicin. Immediate intubation is not required if the neonate's respiratory status is stable. Some medical experts recommend a controlled, elective intubation to avoid unnecessary airway trauma. Surgical management is dependent on the defect. Surgical options include primary closure, staged reduction with a silo or sutureless umbilical closure [17]. In order to prepare the neonate for surgery, a secure airway should be established as well as adequate intravenous access. Due to the nature of the defect, umbilical lines are contraindicated in gastroschisis. Chemical paralysis is generally dependent on the preference of the surgeon and may be required in neonates with a large defect. When defect size or abdominal pressure issues prevent primary closure, placement of a silo allows for gradual reduction in the intestine into the abdominal cavity. With a silo, abdominal contents are gently "squeezed" into the abdomen daily. Once the contents are reduced, the neonate is taken to the operating room for closure. After the defect is closed, nasogastric decompression is continued until return of bowel function.

Special consideration must be taken in regard to fluid management in gastroschisis due to insensible fluid loss and postoperative third-space fluid shifts. Amount of postoperative fluid administration should generally be less than prior to gastroschisis closure and be balanced with perfusion and urine output [18]. See discussion of preoperative fluid management. Potential complications associated with gastroschisis include ileus, sepsis, intestinal atresias, malabsorption, wound infection and necrotizing enterocolitis [16].

2.2. Omphalocele

An omphalocele is a congenital ventral abdominal wall defect of the umbilical ring that results in abdominal viscera herniation and is associated with chromosomal, cardiac and/or genitourinary abnormalities [19]. Immediate postnatal management should include protection of the herniated viscera with sterile saline-soaked gauze, and stabilization of viscera to ensure blood supply to the bowel is not kinked by the weight of the bowel. The neonate may be placed right side down or with towels placed under the bowel to help support the externalized intestine.

Gastric decompression should be initiated with placement of a Replogle tube on continuous low suction to prevent bowel distention. If volume of gastric drainage exceeds approximately 10 mL/kg per 12 hour shift, gastric fluid should be replaced with 0.9% sodium chloride.

Potential problems with omphalocele include risk of hypothermia due to high heat loss from the exposed bowel as well as risk of vasoconstriction, decreased tissue perfusion and metabolic acidosis [19]. Fluids and electrolyte replacement will need to anticipate additional fluid losses due to the specific disease pathology. Maintenance of intravascular fluid volume is necessary to ensure adequate tissue perfusion and preservation of bowel wall perfusion [19, 20].

Other factors to consider include prevention of sepsis by administering broad-spectrum antibiotic therapy. Due to the association with other anomalies, neonates with omphalocele should be evaluated with chest and abdominal radiography, renal and abdominal ultrasound as well as echocardiogram prior to operation [19]. Repair of the defect will be a primary or a staged closure depending on the size of the defect. Potential postoperative complications include significant increase in intra-abdominal pressures that may compromise venous blood return and hemodynamic and/or respiratory stability due to diaphragmatic elevation [19].

Another important consideration in neonates with omphalocele is the risk of pulmonary hypertension [21]. All neonates with omphalocele should be monitored for evidence of pulmonary hypertension between the second and seventh day after birth as they may not initially present with signs of pulmonary hypertension. Diagnosis should be suspected based on increased oxygen requirement and increased pre- and postductal gradient and confirmed by increased right ventricular pressures (greater than 40 mmHg) on echocardiogram [21].

Short-term postoperative complications include necrotizing enterocolitis, prolonged ileus and respiratory distress. If primary closure is done, the neonate will require assisted ventilation and may require muscle relaxants for a time. It is important to ensure adequate ventilation and oxygenation by adjusting inspiratory and end expiratory pressures to maintain adequate lung volumes as the abdominal distention postoperatively may be aggravated by fluid third spacing due to capillary leak syndrome. Postoperative pain management usually requires continuous infusion of morphine and should be titrated according to appropriate neonatal pain scales (see pain section later in chapter) [22]. Long-term complications include prolonged dependence on parenteral nutrition, gastroesophageal reflux, parenteral nutrition-related liver disease, feeding intolerance and neurodevelopmental delay [19]. When bowel function returns postoperatively, initiation of enteral feeds should be done with breast milk or an elemental formula such as Elecare or Neocate, starting with small volumes and advancing slowly [23, 24]. Neonates with giant omphalocele usually require prolonged time to achieve full enteral feeds, especially if complicated by respiratory insufficiency requiring intubation shortly after delivery or symptoms of gastroesophageal reflux postoperatively [24].

2.3. Obstruction

See further detail (**Table 4**).

Type	Presentation	Diagnosis	Preoperative care	Treatment	Postoperative care
Duodenal atresia	Few hours after birth; bilious vomiting, no distention	Abdominal film; "double-bubble" sign	Gastric decompression, IV fluids	Diamond-shaped duodenoduodenostomy	Feeding dependent upon bowel function
Malrotation with volvulus	At 3–7 days; bilious vomiting, rapid deterioration with volvulus	Ultrasound and contrast studies; "upper GI spiral" sign, abnormal location of the superior mesenteric vessels	Gastric decompression, IV fluids, STAT surgery for symptomatic patients	Ladd's procedure	Feeding dependent upon bowel function
Jejunoileal atresia	Within 1 day of birth; vomiting, abdominal distention	Abdominal film; air-fluid levels	Gastric decompression, IV fluids	Resection and anastomosis	Feeding dependent upon bowel function
Meconium ileus	Immediately after birth; abdominal distention, bilious vomiting	Abdominal film; distention, air-fluid levels, "ground-glass" sign	Gastric decompression, IV fluids	Enterostomy if complicated; gastrografin enema	Acetylcysteine (Mucomyst), pancreatic enzymes
Necrotizing ileus	Varied timing; feeding intolerance, abdominal distention, vomiting, bloody stools	Serial abdominal films; distention, ileus, pneumatosis intestinalis, portal venous gas	Gastric decompression, IV fluids, antibiotics for 7 to14 days, serial imaging, STAT surgery if perforated	Resection of necrotic bowel and enterostomy	Feeding reinitiation with slow advancement after antibiotic course completion and normal imaging

Adapted from Ref. [25].

Table 4. Neonatal obstruction [25].

2.4. Necrotizing enterocolitis

Necrotizing enterocolitis (NEC) is the most common emergent neonatal gastrointestinal diseases among premature neonates [26]. The mortality rate of NEC may range from 20 to 30% with the highest mortality in those neonates who require surgery [27]. Often, an inverse relationship between gestational age and frequency of NEC exists. Therefore, the smaller the neonate, the higher the clinical suspicion for this disease.

Typically, NEC presents with feeding intolerance, hematochezia and abdominal distention. Clinical progression of the disease may ensue rapidly from abdominal discoloration, worsening distention with intestinal perforation leading to clinical deterioration with hypotension, metabolic acidosis and thrombocytopenia requiring intensive medical and surgical support. At the moment of suspicion for NEC, the neonate should be placed NPO and gastric decompression initiated. Intravenous fluid hydration must be provided, along with an urgent surgical consultation. Intravenous antibiotics should be started once NEC is suspected that often

include "triple therapy" consisting of Gram-positive, Gram-negative and anaerobic bacteria coverage. Immediate and serial abdominal radiographs should be obtained to assess the presence of pneumatosis intestinalis, one of the hallmarks to diagnose NEC. Laboratory testing should include blood cultures, complete blood count (CBC) to assess for leukocytosis and thrombocytopenia, and C-reactive protein. Serial two-view abdominal radiographs should be obtained to assess for progression. While there are no universally accepted criteria for NEC, Bell's staging system is often used to describe the stages and severity of this disease. The staging is described as follows (see **Table 5**).

Stage/classification	Systemic signs	Abdominal signs	Radiographic signs
IA; suspected	Temperature instability, apnea, bradycardia, lethargy	Gastric residuals, abdominal distention, emesis, heme-positive stool	Normal or intestinal dilation, mild ileus
IB; suspected	Same as above	Gross hematochezia	Same as above
IIA; definite, mildly ill	Same as above	Same as above with absent bowel sounds with or without abdominal distention	Intestinal dilation, ileus, pneumatosis intestinalis
IIB definite, moderately ill	Same as above plus mild metabolic acidosis and thrombocytopenia	Same as above, plus absent bowel sounds, definite tenderness, with or without abdominal cellulitis or right lower quadrant mass	Same as IIA plus ascites
IIIA advanced, severely ill, intact bowel	Same as IIB plus hypotension, bradycardia, severe apnea, combined respiratory and metabolic acidosis, DIC and neutropenia	Same as above, plus signs of peritonitis, marked tenderness and abdominal distention	Same as IIA plus ascites
IIIB advanced, severely ill, perforated bowel	Same as IIIA	Same as IIIA	Same as above plus pneumoperitoneum

Adapted from Ref. [28].

Table 5. Modified Bell's staging criteria for necrotizing enterocolitis [28].

3. Comparison between acute and elective surgical management

Operative intervention of the acutely ill neonate is less desirable but often unavoidable. In situations of intestinal perforation or a hemodynamically compromised neonate, all efforts should be made to ensure a near stable status of the neonate [1, 2, 5]. If a neonate requires emergent surgical intervention, communication with the surgical team, anesthesiology and neonatology team to discuss diagnosis and planned intervention must be made as soon as possible. Most important in management is establishing a stable airway and adequate intravenous or central line access. Pertinent imaging including radiographs and ultrasound should be readily available for evaluation by the surgical team. The neonatal team should ideally be at bedside to intervene in case of clinical deterioration per Pediatric Advance Life Support

(PALS) guidelines. Informed consent for surgery must be obtained with the parents or guardian either in person or via telephone.

One common routine elective operation in neonates is gastrostomy tube placement. A gastrostomy tube or "g-tube" is a small feeding tube that is surgically or percutaneously placed in the stomach for feeding or decompression of air or drainage. Surgical placement is either laparoscopic or open and may be done in association with other procedures [29]. Gastrostomy tubes may be needed for preterm neonates with continued inadequate oral feeding once corrected to term if gastrostomy tube feeding is expected to be needed for greater than 4 weeks. Prior to gastrostomy tube placement, the surgeon may request radiographs to evaluate anatomy of the upper gastrointestinal tract. After gastrostomy tube placement, the neonate may have minor pain at the incision site. Intravenous fluids may be required for the first 24 hour to provide parenteral nutrition to allow the site to heal. Generally, the neonate may be restarted on previous feeds at 25% of the total expected volume, and advanced gradually to full enteral feeds via the g-tube within 24–36 hours as tolerated.. A frequent complication of gastrostomy tubes includes dislodgment, usually within the first 2 weeks after its placement [29]. When this occurs, a physician should replace the tube as soon as possible, so the hole in the stomach does not close. A small amount of leaking is normal and may require protective cream application to the skin. A gastrostomy tube may be left in place permanently or temporarily dependent on the neonate's needs [29].

Another common elective surgical procedure includes inguinal hernia repair. An inguinal hernia repair is an internal opening in the inguinal canal through which fluids and/or intestines may pass through [30]. The neonate may have minor pain at the incision site postoperatively that should be controlled with acetaminophen or small doses of morphine. Neonates should be monitored for postoperative respiratory complications such as apnea and oxygen desaturation. Neonates at risk include those with a history of prematurity, especially if still less than 45 weeks corrected gestational age, and neonates with comorbidities including chronic lung disease, history of necrotizing enterocolitis, anemia, low birth weight or former apnea episodes [31, 32]. Healthy, older neonates may generally be repaired as an outpatient [31].

4. Postoperative care of the neonate

Postoperative management should begin with face-to-face communication between the senior clinician caring for the neonate after surgery and the surgeon as well as the anesthesiologist. The neonatologist should be informed of major events that may have occurred during the surgery, the surgery that was performed, the anesthesia the neonate received during the surgery and postoperatively in recovery (especially if paralytic agents were used), as well as the volume and type of fluids or blood products given during the operation.

Temperature homeostasis is important in the postoperative period. Neonates undergoing operative procedures in the operating room are at increased risk of thermal instability. Hypothermia of postoperative neonates leads to an increased risk of adverse respiratory events including increased need for respiratory and cardiac interventions compared to normothermic neonates [33]. Furthermore, hypothermia may cause protein catabolism, hypokalemia

and changes in glucose metabolism. Postoperative interventions include applying warm temperature regulating blankets, decreasing skin exposure and warming operative rooms [34].

If the neonate remains intubated postoperatively, obtain a blood gas and chest radiography immediately following return to the ICU to assess oxygenation, ventilation, chest expansion and endotracheal tube position. It is important for clinicians to understand postoperative neonates are prone to apnea and periodic breathing while recovering from anesthesia and in response to pain and pain medications. Neonates are also prone to hypoxemia due to transient decrease in functional residual capacity of the lungs and ventilation/perfusion mismatch. Adequate lung tidal volumes of 6–8 mL/kg expiratory lung volumes should be maintained to prevent atelectasis. Blood gas pH should be maintained at 7.35–7.45 with pCO2 of 40–55 for most neonates. Once the neonate is awake and consistently breathing spontaneously, the clinician should rapidly wean the ventilator and extubate per blood gases if possible. Weaning off mechanical ventilation should be weighed against the need for additional pain control. Surgery should be made aware of neonates requiring nasal continuous positive airway pressure (CPAP) or nasal intermittent mandatory ventilation (IMV) postextubation. Ideally, continuous narcotic infusion for pain control should be at a minimum or discontinued prior to extubation. The clinician should also monitor for the development of pulmonary hypertension by clinical symptoms, pre- and postductal oxygen gradient and confirm by echocardiography [1].

Immediate postoperative labs should include evaluation of hemoglobin/hematocrit. If blood loss is over 15% and not already replaced during the operative period, clinicians should consider replacing with packed red blood cells [35, 36]. Electrolytes should be evaluated in the immediate postoperative period and also monitored every 6 hours for invasive procedures or every 8–12 hours for less intensive procedures for the first 24-hours postoperatively [1].

Surgical neonates may have significant third-space losses depending on the magnitude of the procedure. Phases of fluid resuscitation change with time postoperatively. In the immediate postoperative time period, fluid and blood replacement is often required. Postoperative days 2–4 are often phases of third spacing and vascular leak during which some element of fluid replacement is required in conjunction with diuretics to help mobilize fluids. Avoidance of massive anasarca is important. Abdominal compartment syndrome is especially important to consider in the context of abdominal closures with decreased perfusion and the potential for decreased urine output. Gastroschisis patients are especially prone to large fluid losses. If total parenteral nutrition is not immediately available, D5 lactated ringers should be given. Initial fluids should be given at 150–175 mL/kg/day. Total parenteral nutrition should be optimized to include protein of 3–4 g/kg/day to minimize catabolic state and promote wound healing. Dextrose may need to be adjusted postoperatively due to hyperglycemia secondary to stress and increased fluid administration. Therefore, Accuchecks should be monitored frequently, and glucose infusion rate (GIR) should be adjusted. GIR should be maintained 4–8 μg/kg/min to maintain blood glucose levels of 100–160 mg/dL. Electrolytes should be normalized as much as possible [5]. Consideration of starting enteral nutrition should be discussed when the neonate shows intestinal readiness, presence of bowel sounds and passing gas. Clinicians should monitor for postoperative ileus from the surgery and/or ileus due to

pain medications. Antireflux medications should be avoided in the neonate unless for specific surgical cases such as tracheoesophageal fistula where such medications have proven to be necessary. Reflux medications lead to abnormalities of intestinal flora and have been shown to increase neonatal mortality [37].

Special fluid consideration must be made for those neonates with gastroschisis that have undergone repair. Once they are repaired, their fluid losses significantly decrease, and thus, parenteral nutrition must be adjusted shortly after surgical closure. Total fluid administration should be decreased to approximately 140–150 mL/kg/day [38], based on the assessment of the neonate's fluid losses. Clinicians should be cautious of fluid volumes as overhydration may lengthen hospital stay and delay enteral feeding [38].

Hypotension secondary to hypovolemia may be treated with 10–20 mL/kg boluses of normal saline or if hypotension is persistent and severe, the clinician should consider fresh frozen plasma. If anemic, packed red blood cells may be used. Albumin should rarely be used and only with great caution as it may worsen third-space fluid losses in neonates. Low albumin is often partially dilutional and when not exacerbated by dilutional effects, is best addressed through maximizing protein delivery through nutrition. Replacement of any gastric output should be considered with 0.45 normal saline with 10 mEq of potassium chloride per liter. If output is large, consider replacing more frequently (i.e., every 4 hours to run over 4 hours versus once a shift over 1 hour if lower output). Replacement of gastric fluid is important to maintain fluid balance but must be balanced with urine output and overall body edema. Vasopressor therapy may be considered for the critically ill postoperative neonate if fluid replacement is already optimized and neonate remains hypotensive with signs of decreased end-organ perfusion. Steroid therapy to aid adrenal stress response may also improve hemodynamic stability; however, it should be used cautiously as steroids may decrease immune response if there is concern for infection.

Fluid status must be monitored closely, and urine output should be maintained at a minimum of 1 mL/kg/hour. The clinician must balance the neonate's overall fluid status as measured by weight, urine output, body wall edema, blood pressure, heart rate and overall clinical status. Edematous neonates may still have low intravascular volumes, and thus, diuretics would possibly exacerbate hypotension.

Blood pressure should be monitored closely, at least hourly if there is no arterial line access. Hypotension in the postoperative period is considered a sign of hypovolemia until proven otherwise. Skin perfusion should be monitored which can be done by NIRS or perfusion index of pulse oximetry monitoring. All tubes and drains should be monitored closely postoperatively for patency, function and how secure they are attached to the patient. Output of sumps, chest tubes, wound drains and Foley catheters should be followed. Pending resolution of ileus and improvement in outputs each should be removed at the earliest time point to prevent infection with persistent foreign bodies.

Prevention of infection is important. White blood cell count, C-reactive protein trend and bandemia should be monitored and blood cultures obtained if concern for infection rises [1]. Be especially cautious of hygienic precautions when handling tubes, drains and any wound

dressing changes. The need for postoperative antibiotic coverage should be discussed between the neonatal clinician and surgeon.

5. Pain management, sedation and paralysis review

Pain control should be titrated based on the type of surgery. More invasive surgeries will likely require immediate postoperative pain management including a narcotic drip for the first 24 – 48 hours [39]. Consider morphine 20-50 micrograms/kg/hour or Fentanyl 3 micrograms/kg/hour with as needed (PRN) dosing for breakthrough pain. Pain management should be transitioned to PRN dosing when able. Titration of pain medication should be assessed through reliable and accurate neonatal pain assessment scoring tools such as the "Neonatal Pain, Agitation and Sedation Scale" (N-PASS) [40] or "Crying, Requires increased oxygen administration, Increased vital signs, Expression and Sleeplessness" (CRIES) [41]. A combination of behavioral observations such as facial expression, body posture and tone and physiologic symptoms such as heart rate, blood pressure and oxygen saturation should be taken into consideration by the neonatal pain score used [22].

Nonnarcotic pain management methods should be used such as Sweet-Ease and intravenous Tylenol 20 mg/kg/dose every 6 hours for a 24-48 hour period, unless contraindicated or if there is concern for liver dysfunction. The neonate should be monitored closely for urinary retention if Foley catheter is not in place. The stomach should be decompressed. Nonpharmacological pain management includes protective neonatal positioning if possible with the neonate supported in the flex position. Environmental stimulation should be minimized with decreased lighting, noise and touch.

Use of chemical paralytic agents postoperatively should only be used in cases where there is concern for wound dehiscence, large irreducible gastroschisis or patient instability. Paralytics should be used for shortest time possible, as the use will increase the likelihood of third-spacing fluids, urinary retention and anasarca [39].

6. Follow-up of the surgical neonate

The care of a neonate following discharge from the ICU is one that requires a multidisciplinary approach. The patient's pediatrician, neonatologist in the High Risk Follow Clinic (when appropriate), various therapists and the primary surgeon will need to see the neonate after discharge [42]. Follow-up visits include neurodevelopment assessment scales using Bayley III and WPPSI-II scores. While there are certain risk factors innate to sick neonates that make them prone to developmental delay such as prematurity and/or congenital defects, there are data to suggest that neonates who require surgical intervention experience initial developmental delays as compared with their healthy counterparts [43]. While there is ample evidence of suboptimal developmental outcomes in neonates requiring cardiac surgery, the data for those undergoing repair of conditions such as gastroschisis suggest that outcomes are similar to those of their healthy cohorts [44]. Those neonates who have had significant surgical intervention and those with severe outcomes such as short gut syndrome require a lifelong close follow-up with the surgical team.

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