Chapter 31

Pediatric Care

Introduction

The military surgeon must be prepared to address the unique challenges that pediatric patients present, not only in war scenarios, but also in noncombat military operations other than war.

Anatomical and Physiological Considerations

- **Fluid, electrolyte, and nutrition.**
  - Maintenance fluid requirements in children may be estimated using a weight-based nomogram (Table 31-1) or a length-based method, such as the Broselow Pediatric Emergency Tape. There is an increasing realization that hyponatremia caused by hypotonic intravenous fluids is a significant cause of morbidity and mortality in the injured child. Administration of D5½NS with 20 mEq/L of KC1 is acceptable even in infants. Monitoring serum electrolytes serves as is a useful guide in assessing the adequacy of resuscitation. Because infants and small children have limited glycogen stores, administration of glucose early in the resuscitation period (within 6 hours) is critical.

Table 31-1. Hourly Fluid Requirements for Children

Weight (kg)	Hourly Volume	Fluid
Up to 10 kg	4 mL/kg	D5½NS + 20 mEq KCl/L
11–20 kg	40 mL + 2 mL/kg over 10 kg	D5½NS + 20 mEq KCl/L
>20 kg	60 mL + 1 mL/kg over 20 kg	D5½NS + 20 mEq KCl/L

  - Fluid resuscitation is best performed with normal (0.9%) saline at 20 mL/kg boluses. (See Evaluation and Diagnosis.)

- Normal urine output
  -infants: 2 mL/kg/h
  -children: 1 mL/kg/h
  -adults: 0.5 mL/kg/h
- Daily caloric and protein requirements may be estimated based on weight and age (Table 31-2).

Table 31-2. Daily Caloric and Protein Requirements for Children

Age (yrs)	Body Weight (kcal/kg)	Protein (g/kg Body Weight)
0–1	90–120	2.0–3.5
1–7	75–90	2.0–2.5
7–12	60–75	2.0
12–18	30–60	1.5
>18	25–30	1.0

- Breast milk is optimal when initiating oral intake in infants, and offers many advantages over other preparations. Standard infant formulas provide 20 kcal/oz. An estimate of the amount of formula needed to provide 120 kcal/kg/d is:

Infant's weight (kg) × 22-30 =
Amount (in mL) of formula needed q4h.

- If pediatric-appropriate enteral formulas are unavailable, adult preparations may be utilized beyond infancy by diluting them with free water:

100 mL/kg of free water per day for the first 10 kg,
50 mL/kg/day for the second 10 kg,
and then 20 mL/kg/day for every kg over that up to 2.4 L/day.

- Pulmonary.
  - In contrast to adults the most common cause of cardiac arrest in children is respiratory arrest. Hypoxemia can lead to bradycardia with hypoperfusion, followed rapidly by cardiac arrest.
  - Newborns are obligate nasal breathers; thus, nasal airways and nasogastric tubes should be avoided if possible in favor of oropharyngeal airways and orogastric tubes.

- The child's larynx is positioned more anteriorly compared to adults, and a more forward positioning of the head ("sniffing position") will facilitate visualization of the trachea.
- The acceptable range of PaO_2 (60–90 mm Hg) corresponds to an oxygen saturation of 92%–97%. Oxygen saturations in the low 90s are adequate in infants due to increased levels of fetal hemoglobin (Hgb F). Supraphysiologic concentrations of inspired oxygen are unnecessary, and are harmful, especially to preterm infants.
- Infants breathe primarily using their diaphragm; thus, increases in intraabdominal pressure or other problems that limit diaphragmatic movement may significantly impair respiration. An example of this is gastric distension. In the traumatically injured infant or child, gastric decompression is important to preserve respiratory function and prevent vagal stimulation. Children have limited functional residual capacity; therefore, maneuvers such as c-spine and backboard immobilization may impair respiration, especially in the face of gastric distension.

- Cardiovascular.
  - Vital signs by age group are shown in Table 31-3.

Table 31-3. Normal Vital Signs for Age

Age	Weight (kg)	Respiration Rate	Pulse	BP (Systolic)
Premie	<3	40–60	130–150	42 ± 10
Term	3	40	120–140	60 ± 10
1–5 years	~10–20	20–30	100–130	95 ± 30
6–10 years	20–32	12–25	75–100	100 ± 15
Adolescent	50	12–18	70	120 ± 20

  - Cardiac stroke volume in infants is relatively fixed. Therefore, bradycardia or relative bradycardia may be associated with a significant decrease in cardiac output (CO=HR × SV).

Obtaining venous access in a hypotensive child may be extremely difficult and may delay the administration of critically needed fluids or medications. Limit peripheral IV access attempts to two within 90 seconds for the child in shock, then immediately proceed to intraosseous needle access. (See Chapter 7, Shock, Damage Control Resuscitation, and Vascular Access.) NEVER utilize the sternum as a location for IO access in small children. The humerus should be used only as a last resort. In general, the tibial plateau or distal femur are the preferred locations.

- **Burns.**
  - An infant or child's head comprises a greater percentage of the total body surface area, with the lower extremities being a lesser percentage. The area encompassed by the palm of the patient's hand corresponds to approximately 1% of the total body surface area, and may be useful in calculating the total burn surface area (Fig. 31-1).

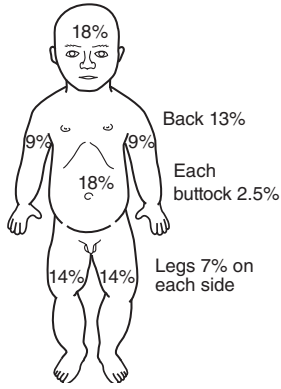

Fig. 31-1. Body surface area percentages for infants and children.

- Gastrointestinal.
  - **Esophageal** reflux is physiologic in the newborn period, and decreases as a child becomes ambulatory, solid food comprises a greater part of the diet, and lower esophageal sphincter tone increases.
  - Upright positioning and institution of thickened feedings often improves symptomatic children.
  - Children (especially infants) are predisposed to hypoglycemia due to their low hepatic glycogen stores. Full-term infants will tolerate NPO status for approximately 5 days (with an appropriate D10 solution). Premature infants will tolerate only 3 days of NPO status prior to the initiation of total parenteral nutrition. Approximately 5–7 mg/kg/min of glucose is necessary to maintain normoglycemia.

- A child's GI tract is very sensitive to insults, including hypoxemia, enteric infection, electrolyte and acid-base abnormalities, and systemic illness. This may be manifest as impaired motility and feeding intolerance.
- Gastroenteritis with diarrhea, often associated with fevers, is also a very common cause of severe dehydration.

- Hematology and blood volume.
  - Infants have a physiologic anemia (hematocrit of 30%–33%) as production of adult hemoglobin (Hgb A) replaces fetal hemoglobin (Hgb F) during the first 3–5 months of life.
  - Estimates of blood volume are as follows:

Age Estimate	Volume (mL/kg)
Newborn	90
Infant	80
School-age child	70

- Renal.
  - Infants and young children have a limited ability to concentrate urine (maximum: 400–600 mOsm/L) and a fixed ability to excrete sodium, and are therefore at risk for hypernatremia if excessive sodium is administered.
  - Maintenance electrolyte requirements:
    1 mEq/kg/day of potassium
    2 mEq/kg/day of sodium
    3 mEq/kg/day of chloride
  - Serum electrolytes should be monitored daily in children who are NPO with significant GI losses or children who are being resuscitated. GI losses such as gastric fluid output should be carefully measured and replaced with the appropriate IV fluids. Bolusing children with potassium-containing fluids can be very dangerous. It is preferable to tolerate mild to moderate hypokalemia while replacing losses very slowly (over 12 hours) while on an EKG monitor, if available. It is much safer to replace ongoing losses as they occur, preferably by the enteral route, than to use an IV bolus for measured deficits.
- **Thermoregulation.**
  - Infants and young children are predisposed to heat loss due to diminished quantities of adipose tissue, and they

compensate poorly for wide fluctuations in ambient temperatures. Children have a higher ratio of body surface area to mass, and therefore are likely to experience increased insensible water loss and become dehydrated more quickly than adults when febrile.

- Reduce exposure to heat loss, and keep infants and children in a regulated warm environment. Active warming measures such as warming IV fluids and using thermal blankets are critical for infants and small children during trauma evaluations and in the operating room. Small children will rapidly become hypothermic if this is not done as part of standard practice.

- **Immune system.**
  - Premature infants have an immature immune system, causing a 60-fold increased risk of sepsis. All elective surgery in infants under 30 days of age requires 48 hours of prophylactic antibiotics (with anaerobic coverage added when appropriate) after the first week of life.
  - Early signs of sepsis may be subtle in infants and may be manifested as lethargy, intolerance to feedings, fever, hypothermia, tachycardia, and irritability before a rise in white blood cell count. Leukopenia and thrombocytopenia in infants and small children may be associated with an overwhelming infectious process.

Evaluation and Diagnosis

- Pediatric cervical spine clearance can be performed with a physical examination in awake children without neurological deficits. If there is no midline tenderness or pain with active motion, the spine can be cleared. Obtunded children, those with focal neurological deficits, and those with tenderness should have further imaging, dictated by imaging modalities available at a given facility. Although children are at higher risk for spinal cord injury without radiographic abnormality (SCIWORA) than adults, most cases may be managed with immobilization alone. Plain films will detect most clinically significant c-spine injuries in children. Unlike in adults, a normal CT of the c-spine in small children will not rule out a ligamentous injury. Pseudosubluxation of C2 on C3 may

be evident on x-ray. If in doubt, continue immobilization of the cervical spine. Because of the larger cranium in infants, the body should be placed on a pad in order to maintain normal anatomic alignment of the airway during backboard immobilization, and sufficient padding should be placed under the occiput to prevent pressure necrosis of the scalp.

- Basic ATLS guidelines should direct the initial assessment and evaluation for all children involved in traumas.
  - Modified Glasgow Coma Scale scores for children < 4 years old:

Verbal Response	Verbal Score
Appropriate words/social smile/fixes/follows	5
Cries, but consolable	4
Persistently irritable	3
Restless, agitated	2
None	1

Treatment

- The treatment algorithm shown here provides the proper sequence for the rapid sequence intubation of the pediatric patient (Fig. 31-2).
  - Avoid succinylcholine in patients with burn or crush injuries, or at risk for increased intracranial pressure.
  - Ketamine may prevent hypotension in patients not in septic shock.

Equipment and Supplies

- Accessory pediatric medical/surgical equipment arranged according to age and weight appears in Table 31-4.
- Surgical instruments.
  - If a pediatric surgical set is not immediately available, a peripheral vascular set will usually contain instruments delicate enough to accomplish most tasks in newborns.

Commonly Used Drugs and Dosages

All doses are IV or IM.

- Phenobarbital: 10–20 mg/kg IV at a rate not to exceed 1 mg/kg/min (maximum dose: 40 mg/kg).
- Diazepam: 0.04–0.3 mg/kg/dose.

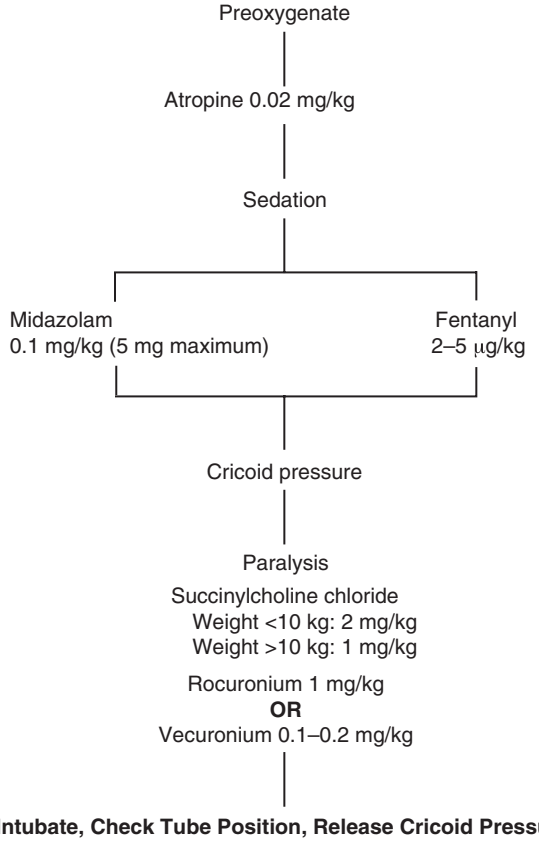

Fig. 31-2. Rapid sequence intubation for the pediatric patient.

- Midazolam: 0.1 mg/kg IV (maximum: 5 mg).
- Atropine: 0.02 mg/kg IV.
- Phenytoin: 15–20 mg/kg IV; administered at 0.5–1.5 mL/kg/min as a loading dose, then 4–7 mg/kg/d IV for maintenance.
- Mannitol: 0.25–1.0 g/kg IV.
- Succinylcholine chloride: 2 mg/kg IV for <10 kg and 1 mg/kg IV for >10 kg.
- Ampicillin: 25–50 mg/kg IV q6h; 100–200 mg/kg/d divided q6h.
- Gentamicin: 4.5–7.5 mg/kg IV qd [once daily dosing (ODD)]; keep doses in manual for q8h dosing.

Table 31-4. Pediatric Resuscitation Equipment and Supplies

	Airway/Breathing							Circulation		Supplemental Equipment			
Age, Weight (kg)	**O_2 Mask**	**Oral Airway**	**Bag Valve**	**Laryngo-scope**	**ET Tube**	**Stylet**	**Suction**	**BP Cuff**	**IV Cath**	**NG Tube**	**Chest Tube**	**Urinary Cath**	**C-collar**
Premie 3 kg	Premie Newborn	Infant	Infant	0 Straight	2.5–3.0 No cuff	6 Fr	6–8 Fr	Premie Newborn	24 gauge	12 Fr	10–14 Fr	5 Fr Feeding	—
0–6 mo 3.5 kg	Newborn	Infant Small	Infant	1 Straight	3.0–3.5 No cuff	6 Fr	8 Fr	Newborn Infant	22 gauge	12 Fr	12–18 Fr	5–8 Fr Feeding	—
6–12 mo 7 kg	Pediatric	Small	Pediatric	1 Straight	3.5–4.0 No cuff	6 Fr	8–10 Fr	Infant Child	22 gauge	12 Fr	14–20 Fr	8 Fr	Small
1–3 yrs 10–12 kg	Pediatric	Small	Pediatric	1 Straight	4.0–4.5 No cuff	6 Fr	10 Fr	Child	20–22 gauge	12 Fr	14–24 Fr	10 Fr	Small
4–7 yrs 16–18 kg	Pediatric	Medium	Pediatric	2 Straight or curved	5.0–5.5 No cuff	14 Fr	14 Fr	Child	20 gauge	12 Fr	20–32 Fr	10–12 Fr	Small
8–10 yrs 24–30 kg	Adult	Medium Large	Pediatric Adult	2–3 Straight or curved	5.5–6.5 Cuffed	14 Fr	14 Fr	Child Adult	18–20 gauge	12 Fr	28–38 Fr	12 Fr	Medium

BP: blood pressure; Cath: catheter; C-collar: cervical collar; ET: endotracheal; Fr: French (gauge); IV: intravenous; NG: nasogastric; O_2: oxygen.

- Metronidazole: 7.5 mg/kg IV q6h.
- Acetaminophen: 15 mg/kg PO q4h.
- Cefazolin: 25–100 mg/kg/d divided q6h–q8h.
- Clindamycin: 15–40 mg/kg/d divided q6h–q8h.
- Hypertonic saline (3%): 5–10 mL/kg.
- Morphine: 0.1–0.2 mg/kg q2h–q4h PRN.
- Ketamine: 0.5–1.5 mg/kg IV over 1 minute >3 months; 2–4 mg/kg IM.

Surgical Management

- Basics.
  - As a general guideline, transverse abdominal incisions should be used in infants. This minimizes the risk of postoperative dehiscence, while still allowing adequate exposure of all areas of the abdomen except the gastro-esophageal junction.
  - Absorbable sutures, such as VICRYL or PDS (2-0), should be used to close the rectus fascia, regardless of the incision. The skin can then be closed using staples or absorbable monofilament suture (eg, MONOCRYL 6-0).
  - Cricothyroidotomy should not be done in children under age 10. If a surgical airway is required, a large-bore IV connected to high flow oxygen can be placed into the cricothyroid membrane or the trachea while preparations are made for an urgent tracheostomy. It is important to allow for passive expiration during this procedure because pneumothoraces can occur if high flow oxygen is administered in the face of an upper airway obstruction. Use of a needle cricothroidomy for more than 45 minutes will result in hypercarbia. Tracheostomy in small children is done as it is in adults. The presence of an esophageal tube is critical to avoid inadvertent injury to the esophagus.
  - The vast majority of thoracic injuries in children can be managed with chest tube alone. Children who present in extremis due to penetrating thoracic injury should undergo a resuscitative thoracotomy similarly to adults. However, for children with blunt trauma, survival after resuscitative thoracotomy is so poor that its use in this setting cannot be justified, particularly in the austere environment.

- When thoracotomy is required in small children, double lumen endotracheal tubes with lung isolation is usually not necessary. Placement of a bronchial blocker or standard endobronchial placement of a single lumen tube will allow for sufficient exposure in small children.

References

Creamer KM, Fuenfer MM, eds. *Pediatric Surgery and Medicine for Hostile Environments*. Fort Sam Houston, TX: Borden Institute; 2016.

Tschudy MM, Arcara KM, eds. *The Harriet Lane Handbook: A Manual for Pediatric House Officers*. 19th ed. Philadelphia, PA: Elsevier Mosby; 2012.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs