# Pediatric Anesthesia Drugs Update:

## Current Indications and Dosage Guidelines

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A major challenge facing pediatric anesthesiologists and general anesthesiologists who occasionally work with children is to administer the correct dose of anesthetic drugs to children of different ages. Most of the time, drugs are administered to children based on their body weight. Usually, this approach is logical and can deliver the appropriate amount of a drug needed to produce the desired pharmacologic effect. However, as we are frequently reminded, children are not miniature adults.

Both qualitative and quantitative aspects of pharmacodynamics and pharmacokinetics are different in children, particularly during infancy. Neonates have reduced clearance of many drugs when compared with infants and adults because of incomplete maturation of their hepatic enzyme systems and reduced glomerular filtration rates. Unfortunately, because of the lack of clinical trials that target children, clinical efficacy and safety assumptions are frequently extrapolated from adult studies. Even when extensive clinical experience and published peer-reviewed articles are available to support appropriate safe use of certain drugs in children, the drug labels may still carry a warning against pediatric use. Common examples include fentanyl in children less than 2 years old, bupivacaine in children under 12 years of age, and dopamine.[1]

Anesthesiologists who care for children must provide the best possible care to their patients. In daily practice, this invariably includes using drugs off-label. Using a drug off-label, however, does not necessarily mean being experimental. Appropriate off-label use of these drugs should not be considered a violation of the standard of care. It simply reflects the lack of financial incentive for many drug companies to conduct proper trials in children and present the results to the Food and Drug Administration for review and proper labeling for pediatric use. This issue has been recently reviewed in an editorial by Coté and Alexander.[1]

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### Perioperative Medications

Routine drugs used in the perioperative period include preanesthetic sedation agents, anticholinergics, analgesics, antiemetics, intravenous (I.V.) and inhalation general anesthetics, local anesthetics, muscle relaxants, opioid analgesics, and reversal agents. Along with these routine drugs, antibiotics, respiratory medication, resuscitation drugs, and vasodilators/β-blockers may be necessary during the patient's perioperative therapy. Medications that may be used to prevent adverse events include antiepileptics, heparin, subacute bacterial endocarditis (SBE) prophylaxis, latex allergy premedication, and narcotic antagonists. In addition, a variety of other medications are used to prevent and treat postoperative pain.[2]

## Table 1. Preanesthetic Sedation Agents

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Chloral hydrate | PO | 50-75 mg/kg | 30-60 min | 4-8 h | Procedural sedation | Hepatic and renal insufficiency | Appropriate monitoring required |
| | PR | 50 mg/kg | 30-60 min | 4-8 h | Procedural sedation | Hepatic and renal insufficiency | Appropriate monitoring required |
| Ketamine | IM | 2-3 mg/kg | 3-4 min | 15-25 min | Preinduction sedation | Increased ICP | Use only in extremely uncooperative children |
| | PO | 6-10 mg/kg | 15-30 min | 30-45 min | Preanesthetic sedation | Increased ICP | Reduce dose if combined with sedatives |
| | I.V. | 0.5-1.0 mg/kg | 1-2 min | 5-15 min | Sedation/ analgesia | Increased ICP | Combine with a sedative/hypnotic |
| Lorazepam | I.V. | 0.03-0.05 mg/kg; maximum dose: 2 mg | 3-7 min | 6-8 h | Preanesthetic sedation | — | — |
| | PO | 0.05 mg/kg | 20-30 min | 6-8 h | Preanesthetic sedation | — | — |
| Methohexital sodium (Brevital, Jones) | PR | 25 mg/kg | 10-20 min | 60-90 min | Preanesthetic sedation | Porphyria | Side effects include hiccups and involuntary movements |
| Midazolam | PO | 0.5 mg/kg; maximum dose: 20 mg | 20-30 min | 45 min | Preanesthetic sedation | — | — |
| | I.V. | 0.05 mg/kg | 1-5 min | 20-30 min | Preinduction sedation | — | — |
| | Nasal | 0.2 mg/kg | 5-10 min | 30-45 min | Preinduction sedation | — | — |
| **Centrally Acting $\alpha_2$-Agonists** | | | | | | | |
| Clonidine | PO | 3-5 mcg/kg | 30-60 min | 8-12 h | Preanesthetic sedation in older patients | Porphyria, Raynaud's syndrome, patients in whom decreased heart rate is undesirable, ages <1-2 y | Useful in hypertensive, opioid-tolerant older patients. May also be administered as a patch |
| Dexmedetomidine (Precedex, Hospira) | I.V. | Loading dose: 0.5 mcg/kg infused slowly over 10 min in dilute solution (20-25 mL). Infusion for patients on a ventilator: 0.25-0.5 mcg/kg/h | Rapid | 2-3 h | Off-label: postoperative sedation in ICU of older patients for spinal surgery; limits opioid requirement and blunting of CNS stress response | Patients in whom reduced heart rate is undesirable | Adjust dosage in patients with hepatic disease; relatively selective $\alpha_2$-receptor agonist; 7 times more specific for $\alpha_2$ than $\alpha_1$ vs clonidine; useful in ventilated patients in the post-op ICU |

**ICP,** intracranial pressure

### *Preanesthetic Sedation Medications*

One of the most commonly used preanesthetic sedation agents is oral midazolam (also available by I.V. and nasal administration). Other commonly used agents (Table 1) include chloral hydrate, ketamine, lorazepam, and methohexital sodium (Brevital, Jones). Less commonly used sedatives are centrally acting $\alpha_2$-agonists (eg, clonidine and dexmedetomidine [Precedex, Hospira]). Drugs that may be used for prophylaxis include latex allergy premedications, agents for SBE prophylaxis, and opioid antagonists (Tables 2 and 3). Analgesics administered for pain control prior to induction may include acetaminophen, acetaminophen with codeine, ibuprofen, ketorolac, and tramadol (Table 4). Antiemetics such as metoclopramide (Table 5) and local anesthetics such as lidocaine (Table 6) may also be administered prior to anesthesia.

### *Intraoperative Medications*

The newer inhalation agents used for general anesthesia such as sevoflurane and desflurane (Suprane, Baxter) have revolutionized the induction and maintenance characteristics of inhalation anesthesia in the pediatric patient (Table 7). Sevoflurane is the first choice for inhalation induction because of its lack of pungency and hemodynamic stability during induction. Desflurane, on the other hand, is contraindicated for induction in children because of its pungency and ability to produce laryngospasm. However, desflurane is highly desirable during maintenance of anesthesia because of its low solubility, which results in rapid awakening. Low flows are often used to reduce the cost of desflurane. Over a long period of time, sevoflurane tends to behave like isoflurane because of its similarly high fat/blood solubility coefficient.

For older children and adolescents who may dislike inhalation induction, topical cutaneous local analgesics such as lidocaine–prilocaine cream and lidocaine 4% are used (Table 6). They can be applied to the dorsum of the hands to provide a pain-free I.V. cannulation. The advent of propofol has virtually replaced thiopental (Pentathol, Hospira) for I.V. induction at Children's National Medical Center in Washington, DC. Propofol is a drug with unique properties. It has well-known antiemetic properties and is commonly used as an infusion during total I.V. anesthesia for sedation during painless procedures such as computed tomography scans and magnetic resonance imaging (MRI) because of its rapid onset and offset. The only disadvantage of this drug is the pain on injection, which can be ameliorated with the addition of lidocaine (1-2 mg/mL, immediately preceding injection). The advent of the laryngeal mask airway (LMA) in pediatric anesthesia, and the use of short-acting narcotics and propofol for endotracheal intubation for LMA insertion have decreased the need for paralysis. This enables the maintenance of spontaneous ventilation during the case.

The arrival of newer, short-acting nondepolarizing muscle relaxants like rocuronium (Zemuron, Organon) and mivacurium* (Mivacron, Abbott) have challenged the routine use of succinylcholine in children for intubation in nonemergent cases (Table 8). Similarly, for longer surgical cases, infusions of vecuronium have replaced the use of pancuronium. Cisatracurium (Nimbex, Abbott) causes less histamine release and undergoes Hoffman elimination, making it useful in the renally compromised patient.

Anticholinergics may be used prior to anesthesia to decrease salivary secretion, or during anesthesia to increase heartbeat (Table 9). Reversal agents may be given to offset the effects of a muscle relaxant (Table 10). Vasodilators may be used during anesthesia to control blood pressure and prevent hypertension (Table 11). In addition, respiratory medications may be given during anesthesia to prevent bronchospasms and postextubation croup symptoms (Table 12). Caffeine citrate (Cafcit Injection, Mead Johnson) can be used to treat postanesthesia apnea in neonates who were born prematurely (Table 17).

Since children generally do not like injections, many injectable drugs are given after anesthesia is induced. Most pediatric anesthesiologists use this approach when administering antibiotic SBE prophylaxis (Table 2).

Newer narcotic and nonnarcotic opioid analgesics have improved pediatric pain management in the perioperative period (Table 13). Infusions of ultrashort-acting narcotics like remifentanil (Ultiva, Abbott), with a $\beta$ half-life of 8 to 10 minutes, have simplified the intraoperative management of children during intensely stimulating procedures like laryngotracheal endoscopy and laser procedures. Many routine surgical procedures such as tonsillectomies and genitourinary surgery require intraoperative antibiotic administration (Table 14).

Innovative routes of administering new and old narcotics (dermal, transmucosal, and nasal), as well as combining drugs to obtain the additive effects of both while decreasing the side effects of each individual drug, have become prevalent techniques in pediatric anesthesia. For example, the anesthesiologist may add various drugs to local anesthetics administered during caudal blockade to increase the duration and potency. The addition of many drugs like morphine, ketamine, bupivacaine, and reversal agents such as neostigmine (Prostigmin, Valeant) have been extensively studied with encouraging results. Regional anesthesia in children has seen a major increase in the utilization of single-shot and continuous caudal, lumbar, and thoracic epidural anesthesia initially with bupivacaine and then with ropivacaine (Naropin, AstraZeneca) alone or in combination with fentanyl. Some newer local anesthetics such as ropivacaine are especially advantageous in infants who have less protein-binding ability than older children (Table 6). Ropivacaine is currently used in infants for long-term infusion because of its lesser potential for toxicity.

### *Postoperative Treatment*

A wide range of drugs can be useful in the immediate postoperative period. The postoperative period has seen tremendous changes with the initiation of

**Mivacurium is no longer available from manufacturer.*

## Table 2. Agents for Prophylaxis of Adverse Events

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| *Latex Allergy Premedication* | | | | | | | |
| Diphenhydramine | PO | 1 mg/kg × 3 | 3-60 min | 6-8 h | Latex allergy prophylaxis | — | 1 dose at 6 PM and midnight on night before, and 6 AM on day of surgery |
| Prednisone | PO | 1 mg/kg × 3 | 3-60 min | 6-8 h | Latex allergy prophylaxis | — | 1 dose at 6 PM and midnight on night before, and 6 AM on day of surgery |
| Ranitidine | PO | 2-3 mg/kg × 2 | 1-3 h | 8 h | Latex allergy prophylaxis | Competitive inhibition of histamine at $H_2$ receptors | 1 dose at 6 PM; repeat at 6 AM on day of surgery |
| *SBE Prophylaxis*[3] | | | | | | | |
| Amoxicillin | PO | 50 mg/kg; maximum dose: 2 g | 1 h | NA | Dental/PO/ ENT procedures | — | — |
| Ampicillin | I.V. | 50 mg/kg; maximum dose: 2 g | Rapid | NA | Dental/PO/ ENT procedures | — | — |
| Cefazolin | I.V. | 25 mg/kg; maximum dose: 1 g | Rapid | NA | Penicillin-allergic patients | — | — |
| Clindamycin phosphate | I.V. | 20 mg/kg; maximum dose: 600 mg | Rapid | NA | Penicillin-allergic patients | — | Give I.V. infusion slowly (over 30 min) to avoid hypotension |
| Gentamicin | I.V. | 2 mg/kg; maximum dose: 120 mg | Rapid | NA | GU/GI and high-risk patients | — | Give in addition to ampicillin |
| Vancomycin | I.V. | 20 mg/kg; maximum dose: 1 g | Rapid | NA | Penicillin-allergic patients | Red man syndrome; anaphylaxis | Give I.V. infusion slowly (over 30-60 min) to avoid hypotension |



patient-controlled analgesia alone or with basal infusion and, in younger or developmentally delayed children, nurse-assisted analgesia. Patient-controlled epidural analgesia has been successfully used in older children. In rare instances, resuscitation medications may be needed (Table 15). A variety of oral medications are used for pain control, including the older nonspecific nonsteroidal anti-inflammatory drugs (NSAIDs; Table 4). Specifically, pharmacologic studies on the safety of weaker analgesics such as acetaminophen have enabled anesthesiologists to use them earlier and in much higher doses rectally to be effective in the postoperative period.

Postoperative nausea and vomiting (PONV) is one of the main causes for prolonged hospital stay, patient discomfort, and parental dissatisfaction. Newer antiemetic selective 5-hydroxytryptamine (5-$HT_3$) receptor antagonists like ondansetron (Zofran, GlaxoSmithKline), dolasetron (Anzemet, Sanofi-Aventis/Organon), and granisetron (Kytril, Roche) have been found to be effective in PONV prophylaxis and therapy (Table 5).

### Combination Therapy

A typical routine pediatric anesthetic often requires the administration of 4 to 6 different drugs. An inguinal hernia repair, for example, would require the child to receive oral midazolam premedication 25 to 35 minutes before scheduled surgery if indicated. This would be

## Table 3. Opioid Antagonists and Agonist/Antagonist Combination

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| *Opioid Antagonists* | | | | | | | |
| Naloxone | I.V. | 5-10 mcg/kg | 1-2 min | 60 min | Pure opioid antagonist | — | May repeat as necessary |
| Naloxone HCl injection | IM | 5-10 mcg/kg | 2-5 min | 1-4 h | Pure opioid antagonist | — | May be given via ET tube |
| Naloxone | Infusion | 0.5-1.0 mcg/kg/h | 2-5 min | 1-4 h | Pure opioid antagonist | — | Relieves itching without reversal of analgesia |
| *Opioid Agonist/Antagonist* | | | | | | | |
| Nalbuphine | I.V. | 0.1-0.2 mg/kg | Rapid | 3-6 h | Patients with mild to moderate pain who are allergic to mu-receptor agonists | May precipitate withdrawal in opioid-dependent patients | Agonist at kappa and sigma receptors; antagonist at mu receptor; reduce dose in patients with hepatic impairment |

## Table 4. Perioperative Analgesics for Pain Control

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Acetaminophen | PR | 40 mg/kg; maximum dose is 90 mg/kg/d; less in neonates | 60-90 min | 4-6 h | Analgesia | — | — |
| | PO | 20 mg/kg | 30-60 min | 4-6 h | Analgesia | — | Best used on a scheduled basis (not prn) |
| Acetaminophen/ codeine phosphate | PO | 5 mL: ages 3-6 y<br>10 mL: ages 7-12 y | 30-60 min | 4-6 h | Analgesia | Allergy to codeine | — |
| Ibuprofen | PO | 4-10 mg/kg | 30-60 min | 4-6 h | Analgesia | — | — |
| Ketorolac | I.V. | 0.5 mg/kg loading dose | 30 min | 0.25 mg/kg q4-6h | Acute pain | Use with caution in asthmatics | May cause GI, platelet, and renal damage |
| Tramadol | PO | 1-2 mg/kg loading dose | 1 h | 8 h | Postoperative analgesia, acute pain | Interaction with ondansetron | May be combined with acetaminophen; minimal respiratory depression |

## Table 5. Antiemetics for PONV Prevention

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contraindications | Comments |
|---|---|---|---|---|---|---|---|
| Dexamethasone | I.V. | 0.15 mg/kg; maximum dose: 8-12 mg | 30-60 min | 6-12 h | PONV | — | Maximum dose can be up to 0.5 mg/kg in T&A surgery. Also used for croup, increased ICP |
| Dolasetron (Anzemet, Sanofi-Aventis/Organon) | I.V. | 0.35 mg/kg | 15 min | 4-8 h | PONV | — | Selective 5-$HT_3$–receptor antagonist, risk of QT prolongation |
| Droperidol | I.V. | 10-70 mcg/kg | 15-30 min | 4-8 h | PONV | — | Risk of QT prolongation, sedation in high doses |
| Granisetron (Kytril, Roche) | I.V. | 40 mcg/kg | 1-3 min | 24 h | PONV | — | Selective 5-$HT_3$–receptor antagonist |
| Metoclopramide | I.V. | 0.1-0.15 mg/kg; maximum dose: 10 mg | 1-3 min | 1-2 h | PONV | GI obstruction | |
| Ondansetron (Zofran, GlaxoSmithKline) | I.V. | 0.1 mg/kg; maximum dose: 4 mg | 30 min | 4-8 h | PONV | Interaction with tramadol | Selective 5-$HT_3$–receptor antagonist |
| | PO | 4-8 mg | 30-60 min | 4-8 h | PONV | — | — |
| | ODT | 4-8 mg | 30-60 min | 4-8 h | PONV | — | — |
| Prochlorperazine | PO, PR | 0.1 mg/kg | 60 min | 4 h | PONV | — | May cause sedation, extrapyramidal reactions |
| Promethazine | PO, PR | 0.25-0.5 mg/kg | 30 min | 4-6 h | PONV | — | May cause sedation |



followed by a sevoflurane and nitrous oxide inhalation induction. A short-acting muscle relaxant, eg, mivacurium*, would be used to facilitate tracheal intubation or propofol might be used for LMA insertion. Sevoflurane or desflurane would be used for the maintenance of anesthesia with spontaneous ventilation if the LMA is used. A caudal block or an ilioinguinal/iliohypogastric nerve block with bupivacaine or ropivacaine would be used for intraoperative and postoperative analgesia. Rectal acetaminophen would be inserted while the child is asleep to provide basal analgesia at home. Ondansetron may be required if PONV develops in the postanesthesia care unit (PACU). If additional analgesia in the PACU is required, I.V. fentanyl or morphine may be ordered. Oral acetaminophen with or without codeine may be prescribed for home use. Patients who undergo longer or more complex surgeries may need additional medications. An intermediate-acting muscle relaxant, eg, rocuronium, may be used repeatedly during the case (Table 8). A reversal agent such as neostigmine, combined with I.V glycopyrrolate, would be needed at the end of the case (Tables 9 and 10). Children who have congenital cardiac defects may require antibiotics for SBE prophylaxis (Table 2).[3] These can be given orally before surgery or intravenously immediately following anesthesia induction.

### I.V. Administration

Although I.V. induction of anesthesia is not favored by most children, I.V. drugs can be used following an inhalation induction once an I.V. line is established. This can be invaluable in patients undergoing airway surgery, where a total I.V. technique using a general anesthetic such as propofol and an analgesic such as remifentanil would leave the airway clear from anesthetic gases. Propofol also is widely used for sedation in children undergoing MRI examinations. Another sedative option for these patients includes oral or rectal administration of chloral hydrate.

A healthy adolescent being treated for repair of a pectus deformity may receive cutaneous analgesia with lidocaine or the newer alternatives (Table 16) such as the

*Mivacurium is no longer available from manufacturer.*

## Table 6. Local Anesthetics for Intraoperative Sensory Blockade and Perioperative Pain Control

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contraindications | Comments |
|---|---|---|---|---|---|---|---|
| *Local Anesthetics* | | | | | | | |
| Bupivacaine | Caudal | 2.5 mg/kg | 5-15 min | 4-6 h | Intra- and postoperative analgesia | — | — |
| | Epidural | 0.1-0.4 mg/kg/h | 5-15 min | 4-6 h | Postoperative analgesia | — | Reduce dose by 50% in infants |
| | Spinal | 0.5-1.0 mg/kg | 5-15 min | 4-6 h | Neonatal surgery | — | — |
| Chloroprocaine HCl injection | Epidural | 1.0-1.5 mL/kg of 3% chloroprocaine (preservative free) | Rapid | 30-60 min | Neonatal surgery; peripheral and epidural anesthesia | Plasma cholinesterase deficiency | Ester-type, short-acting, rapid metabolism; useful in neonates with liver dysfunction |
| Cocaine HCl, 4% or 10% viscous solution | Topical (nasal mucosa) | 1.0-1.5 mg/kg | Rapid | 60-90 min | Nasal surgery | Addiction potential, coronary artery disease, intraocular or I.V. routes | Sensitizes myocardium to catecholamines; use with caution in patients on MAO inhibitors or epinephrine |
| Lidocaine | Topical | 3-4 mg/kg | 1-3 min | 20-30 min | Mucosal topical anesthesia | — | Rapid absorption from tracheal mucosa |
| | Infiltration | 5-7 mg/kg | 2-5 min | 1-2 h | Local infiltration, nerve blocks | — | Epinephrine increases duration and delays absorption |
| Lidocaine 4% | Topical | Apply ¼″ thick layer | 30 min | 30-60 min | Venipuncture, minor dermal procedures | Not for mucosal membranes | Watch for accidental ingestion by small children |
| Lidocaine 2.5% and prilocaine 2.5% | Topical | Apply ¼″ thick layer | 45-60 min | 30-60 min | Venipuncture, minor dermal procedures | G6PD deficiency | Use on intact skin; occlusive dressing required |
| Ropivacaine (Naropin, AstraZeneca) | Caudal | 2.5 mg/kg | 5-15 min | 4-6 h | Intra- and postoperative analgesia | — | Less toxicity, less motor weakness than caused by bupivacaine |
| | Epidural | 0.1-0.4 mg/kg/h | — | — | Postoperative analgesia | — | — |
| Tetracaine HCl injection solution (Pontocaine, Abbott) | Spinal | 0.6-1.0 mg/kg (in infants) | 3-5 min | 60-90 min | Neonatal surgery | — | Longer duration if given with epinephrine wash |

## Table 7. General Anesthetics

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| *Inhaled* | | | | | | | |
| Desflurane (Suprane, Baxter) | Inhaled | MAC: 5%-9% | 1-2 min | 2-6 min | Induction and maintenance of anesthesia | — | Side effects include coughing and laryngospasm if used for induction |
| Halothane | Inhaled | MAC: 0.80% | 2-3 min | 4-16 min | Induction and maintenance of anesthesia | — | — |
| Isoflurane | Inhaled | MAC: 1.2%-1.9% | 4-6 min | 4-12 min | Maintenance of anesthesia | — | — |
| Sevoflurane | Inhaled | MAC: 2.5%-3.3% | 1-2 min | 4-8 min | Induction and maintenance of anesthesia | — | — |
| *I.V.* | | | | | | | |
| Etomidate | I.V. | 0.3-0.5 mg/kg | 1 min | 3-5 min | Induction of anesthesia | — | Has minimal cardiovascular effects. Depresses adrenocortical responses to stress for 4-8 h |
| Propofol | I.V. | 2.0-3.5 mg/kg | 1 min | 2-6 min | Induction of anesthesia | — | Add lidocaine 1-2 mg/mL to reduce pain with injection |
| | I.V. infusion | 150-300 mcg/kg/min | 1 min | 2-8 min | Maintenance of anesthesia | — | — |
| Thiopental sodium (Pentathol, Hospira) | I.V. | 5-6 mg/kg | 1 min | 4-15 min | Induction of anesthesia | Acute intermittent porphyria | Increase dose requirement after burn injury |

## Table 8. Muscle Relaxants for Intubation and Intraoperative Muscle Relaxation

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Atracurium | I.V. | 0.3-0.5 mg/kg | 2-3 min | 30-60 min | Muscle relaxant | — | May cause histamine release, Hoffman elimination, ester hydrolysis |
| Cisatracurium (Nimbex, Abbott) | I.V. | 0.1 mg/kg | 2-3 min | 30-60 min | Muscle relaxant | — | Less histamine release, useful in renal failure patients, Hoffman elimination |
| Mivacurium* (Mivacron, Abbott) | I.V. | 0.2-0.3 mg/kg | 2-3 min | 10-15 min | Muscle relaxant | — | May cause histamine release in patients with pseudocholinesterase deficiency of prolonged duration |
| Pancuronium | I.V. | 0.06-0.10 mg/kg | 3-5 min | 60-90 min | Muscle relaxant | Renal failure | May cause tachycardia |

* No longer available from manufacturer.

*continues on page 113*

## Table 8. Muscle Relaxants for Intubation and Intraoperative Muscle Relaxation (continued)

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Rocuronium (Zemuron, Organon) | I.V. | 0.6-1.0 mg/kg | 1.0-1.5 min | 30-60 min | Muscle relaxant | Renal failure | Causes pain on injection |
| Succinylcholine | I.V. | 1-2 mg/kg | 0.5-1.0 min | 3-6 min | Rapid sequence intubation | MH, burns, myopathies, muscular dystrophies | Risk of hyperkalemia, MH in patients with pseudocholinesterase deficiency of prolonged duration |
| | IM | 4-5 mg/kg | 1.5-3.0 min | 10-20 min | Intubation in infants without an I.V. | — | Less side effects than I.V. administration |
| Vecuronium | I.V. | 0.04-0.10 mg/kg | 2-3 min | 20-40 min | Muscle relaxant | Renal failure, hepatic failure | — |

## Table 9. Anticholinergic Agents

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contraindication | Comments |
|---|---|---|---|---|---|---|---|
| Atropine | I.V. | 20 mcg/kg | 1 min | 45-60 min | Anticholinergic | Glaucoma, fever, tachycardia | May be given via ET tube |
| | IM | 20-40 mcg/kg | 10-20 min | 60-90 min | Anticholinergic | Glaucoma, fever, tachycardia | — |
| | PO | 20-40 mcg/kg | 30 min | 60-90 min | Anticholinergic | Glaucoma, fever, tachycardia | — |
| Glycopyrrolate | I.V. | 10 mcg/kg | 1 min | 2-3 h | Anticholinergic | Glaucoma, fever, tachycardia | — |
| Scopolamine | I.V. | 5-10 mcg/kg; maximum dose: 0.3 mg | 5-10 min | 2 h | Drying of saliva | Fever, tachycardia | Crosses blood–brain barrier |
| | IM | 10 mcg/kg | 30-60 min | 4-6 h | Drying of saliva, pre-op sedation | — | — |
| Scopolamine (Transderm Scop, Novartis Consumer) | Patch | 1 patch (0.33 mg) | 4 h | 72 h | PONV, motion sickness | — | Transdermal use for children >12 y |

## Table 10. Reversal Agents To Counteract Effects of Muscle Relaxants

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indication | Comments |
|---|---|---|---|---|---|---|---|
| Edrophonium | I.V. | 0.5-1.0 mg/kg | 1-2 min | 60 min | Muscle relaxant antagonism | — | Acetylcholinesterase inhibitor; combine with anticholinergic |
| Neostigmine (Prostigmin, Valeant) | I.V. | 50-70 mcg/kg | 5-10 min | 1-2 h | Muscle relaxant antagonism | Phase I block of succinyl-choline | Acetylcholinesterase inhibitor; combine with anticholinergic |
| Physostigmine | I.V. | 10-20 mcg/kg | 2-5 min | 1-5 h | Reversal of anticholiner-gic toxicity | GI obstruc-tion, asthma | Acetylcholinesterase inhibitor; monitor for bradycardia |

## Table 11. Vasodilators/β-Blockers for Blood Pressure Control

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Alprostadil Injection | Infusion | 0.01-0.40 mcg/kg/min | Rapid | 5-10 min | Maintain patency of ductus arteriosus | — | May cause fever, apnea, seizures; use caution in renal failure patients |
| Esmolol | I.V. | 0.1-0.5 mg/kg | 2-4 min | 10-30 min | Hypertension, SVT control | Heart block, asthma | Class II antiarrhythmic agent |
| | Infusion | 100-200 mcg/kg/min | 2-4 min | 10-30 min | Tetralogy of Fallot spells | — | — |
| Fenoldopam | Infusion | 0.2-1.2 mcg/kg/min | 4-5 min | 5-10 min | Hypotension, blood pressure control | — | — |
| Hydralazine | I.V. | 0.1-0.2 mg/kg | 5-20 min | 2-6 h | Hypertension control | — | — |
| Labetalol | I.V. | 5 mg slow boluses | 2-5 min | 2-4 h | Blood pressure control | Heart block, asthma | — |
| Nitroglycerin | Infusion | 1-3 mcg/kg/min | Rapid | 3-5 min | Blood pressure control | — | — |
| Nitroprusside | Infusion | 0.5-3.0 mcg/kg/min | 30-60 sec | 1-3 min | Hypotension, blood pressure control | — | — |



S-Caine patch (Synera™, Endo Pharmaceuticals), which have faster onset and do not produce vasoconstriction. If the patient desires or if the physician thinks it is beneficial, premedication with oral midazolam may be given 30 minutes before surgery. I.V. induction in the operating room would then be given using propofol mixed with lidocaine, followed by rocuronium and fentanyl to facilitate tracheal intubation. Maintenance of anesthesia would be achieved with desflurane, oxygen, and a carefully placed thoracic epidural catheter before surgery for intra- and postoperative analgesia. A local anesthetic such as bupivacaine would then be used during surgery, and combined with fentanyl, continued in the postoperative period for further analgesia. A basal infusion and patient-controlled mode would allow the patient more autonomy over his or her pain control. A prophylactic antiemetic such as ondansetron given as needed and an antihistamine would make the patient comfortable in the postoperative period.

In children undergoing major surgery when significant blood loss is anticipated (eg, spinal fusion, cardiopulmonary bypass) drugs such as aprotinin (Trasylol, Bayer) and aminocaproic acid can be used as boluses and infusions to control bleeding. Coagulation

## Table 12. Drugs To Treat Bronchospasm

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Albuterol | Inhaler | 1-2 puffs; MDI provides 90 mcg/dose | 5-15 min | 2-3 h | Perioperative bronchospasm | — | — |
| Albuterol | Nebulized | 0.10-0.25 mg/kg; maximum dose: 5 mg in 2 mL normal saline | 5-15 min | 2-3 h | Perioperative bronchospasm | — | — |
| Epinephrine (racemic) | Nebulized | 0.25-0.5 mL of 2.25% solution in 3 mL normal saline | 5-10 min | 1-3 h | Perioperative bronchospasm, postextubation croup symptoms | — | Rebound edema may occur |



factor VIIa, recombinant (NovoSeven, Novo Nordisk) is specifically useful in patients with hemophilia A or B, when inhibitors to factors VIII or IX are present, and in clinical scenarios involving excessive bleeding (Table 17).

The recent trend of avoiding sharp needles when administering injectable drugs to patients poses another challenge for anesthesiologists when treating children in whom the calculated appropriate doses of many drugs are dispensed in very small volumes. The use of safe needleless devices such as stopcocks or valved injection ports (eg, the Clave Needleless I.V. System [Life Assist, Inc], and SmartSite Needle-Free System [Alaris Medical Systems]) for I.V. drug injections can affect the accuracy of drug administration. Although the internal dead space of these devices is small, it can result in major inaccuracies when small volumes of drugs (<0.3 mL) are injected, as typically happens in infants and small children.[4] Injection through a stopcock is the least accurate method, especially when no flushing is employed. The valved Clave Needleless I.V. System can deliver accuracy close to that of a needle, especially with flushing. The technique of flushing has a considerable effect on the total amount of drug injected. If flushing is performed using the same syringe that delivered the drug, the additional trace of drug contained in the dead space of the syringe can significantly increase the delivered dose. It is therefore recommended that a separate syringe, not containing traces of the injected drug, be used for flushing. When using a stopcock for bolus dosing, diluting the intended dose to a minimal volume of 0.5 mL, followed by flushing, will ensure accurate dosing.[4]

### *Minimizing the Pain of Venipuncture*

In addition to being humane, minimizing the pain of venipuncture increases the chances of a successful outcome by encouraging the child's cooperation and preventing movement. Intracutaneous injection of lidocaine traditionally has been the anesthetic of choice for providing a numbing effect prior to venipuncture. However, patients undergoing these procedures often fear needles and the discomfort associated with injections. Topical creams for percutaneous local anesthesia such as EMLA (AstraZeneca), Ferndale L.M.X.4 (formerly ELA-Max), and Synera are pain-free alternatives to injected intradermal anesthesia (Table 16).

EMLA is an emulsion of lidocaine (2.5%) and prilocaine (2.5%) in a 1:1 ratio. For optimal effect, EMLA cream must be applied in a thick layer and covered with an occlusive dressing for 60 minutes before venipuncture. EMLA can significantly decrease venipuncture and I.V. insertion pain in 85% of appropriate patients.[5] However, it also can lead to skin blanching and vasoconstriction, which can make I.V. cannulation difficult. Applying glyceryl trinitrate ointment after EMLA removal promotes vasodilation and increases the ease of cannulation after EMLA application in school-aged children.[6] Because young children may rub off or even swallow the cream and dressing, a bandage should be placed over the occlusive dressing.

Ferndale L.M.X.4 (4% lidocaine delivered in a liposomal vehicle) provides a longer duration of analgesia because the lipid carrier prolongs the localization of the lidocaine anesthetic. Ferndale L.M.X.4 acts more quickly than EMLA and does not require an occlusive dressing.[7]

Synera comprises a eutectic mixture of 70 mg lidocaine and 70 mg tetracaine in a 1:1 ratio by weight, a bioadhesive layer, a heating element that generates a controlled amount of heat (39°C to 41°C), and a film cover. The absorption of tetracaine is negligible, primarily as a result of dermal metabolism by nonspecific esterases and rapid clearance by plasma pseudocholinesterases. This heat generation and skin warming allows the desirable effect of vasodilation instead of vasoconstriction seen after EMLA. Synera was shown to have onset of analgesia after 20 to 30 minutes of application in children.[8]

## Table 13. Opioids for Perioperative Analgesia and Pain Management

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Codeine | PO | 0.5-1.0 mg/kg | 30-60 min | 4-6 h | Postoperative analgesia | — | Usually taken in combination with acetaminophen |
| | IM | 0.5-1.0 mg/kg | 10-20 min | 4-6 h | Postoperative analgesia | — | I.V. use results in histamine release |
| Fentanyl | I.V. | 1-2 mcg/kg | 2-5 min | 30-60 min | Intra- and postoperative analgesia | — | Causes chest wall rigidity if given rapidly |
| | Nasal | 2 mcg/kg | 5-7 min | 30-60 min | Analgesia (emergence agitation) | — | — |
| Fentanyl (Duragesic, Janssen) | Patch | Variable (25 mcg/h system) | 12-18 h | 48-72 h | Chronic pain | — | — |
| Fentanyl | PO transmucosal | 15-20 mcg/kg | 10-15 min | 30-60 min | Breakthrough cancer pain | — | — |
| Hydromorphone | I.V. | 15 mcg/kg | 2-5 min | 4-6 h | Postoperative analgesia | Biliary tract spasm | Risk of respiratory depression, histamine release |
| | Epidural | 3 mcg/kg | 5-7 min | 8-16 h | Postoperative analgesia | — | 10 mg morphine=1.5 mg hydromorphone |
| | PCA | 3 mcg/kg | 1-2 min | 10-20 min | Sickle cell pain, cancer pain | — | Has more side effects than morphine; does not have active metabolites |

*continues on page 117*



### Emerging Therapies

#### *Sugammadex*

The nondepolarizing effects on skeletal muscle relaxation are often reversed by the administration of an acetylcholinesterase inhibitor in order to achieve spontaneous ventilation after surgery. Because these agents increase acetylcholine at both the neuromuscular junction and the muscarinic receptors, an anticholinergic agent also is required to prevent parasympathetic adverse effects. Some recovery of neuromuscular function is necessary before an acetylcholinesterase inhibitor is administered, as a relative pharmacologic ceiling effect is seen with inhibition of acetylcholinesterase.

The promising new modified gamma-cyclodextrin derivative sugammadex (Organon; not yet FDA-approved) does not interact with cholinergic mechanisms to elicit reversal. It acts as a selective relaxant binding agent and forms a 1:1 complex (chemical encapsulation) with steroidal nondepolarizing neuromuscular blockers in the plasma, lowering the effective concentration available at the receptor. Its selectivity avoids the inhibition of nondepolarizing agents in the benzylisoquinolinium class. Unlike acetylcholinesterase inhibitors, sugammadex is effective even when administered during profound blockade, nor does it require coadministration of an anticholinergic agent.

Sugammadex provides a novel mechanism of action for reversal of the neuromuscular block induced by nondepolarizing aminosteroidal agents.[9] It has the potential to immediately reverse the paralysis produced by a full intubating dose of rocuronium (1.2 mg/kg) in any patient without requiring physicians to wait for the patient's muscle twitches to reappear, as was the case in the past. The drug appears to be relatively safe. In a recent study of 43 adults, sugammadex did not produce any serious adverse effects or signs of recurrence of blockade when increasing doses (2.0, 4.0, 8.0, 12.0, or 16.0 mg/kg) were administered. Neuromuscular function was monitored by acceleromyography, using train-of-four nerve stimulation. Recovery time, defined as the time from the start of administration of sugammadex to

## Table 13. Opioids for Perioperative Analgesia and Pain Management (continued)

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Meperidine | IM | 1.0-1.5 mg/kg | 10-15 min | 2-4 h | Postoperative analgesia | — | — |
| | PO | 1.0-1.5 mg/kg | 15-30 min | 2-4 h | Postoperative analgesia | — | — |
| Methadone | I.V. | 0.1 mg/kg | 5-10 min | 4-12 h | Severe pain, detoxification | — | — |
| | PO | 0.1-0.2 mg/kg | 30-60 min | 4-12 h | Chronic pain, withdrawal symptoms | — | — |
| Morphine | I.V. | 0.1 mg/kg | 2-5 min | 2-4 h | Intra- and postoperative analgesia | Biliary tract spasm | Risk of respiratory depression, histamine release |
| | Spinal | 10 mcg/kg | 15-30 min | 18-24 h | Postoperative analgesia | — | Use only preservative-free morphine sulfate; may cause itching, retention |
| | Epidural | 50-70 mcg/kg | 60-90 min | 8-16 h | Postoperative analgesia | — | Use only preservative-free morphine sulfate; may cause itching, retention |
| | PCA | 20 mcg/kg | 5-10 min | 8-15 min | Postoperative analgesia, acute pain | — | Morphine-6-glucuronide accumulates in renal failure |
| Remifentanil (Ultiva, Abbott) | I.V. infusion | 0.05-2.0 mcg/kg/min | 1 min | 5-10 min | Operative analgesia | — | No residual post-operative analgesia |
| Sufentanil | I.V. infusion | 0.2-0.5 mcg/kg/h | 1-3 min | 30-60 min | Operative analgesia | — | Causes chest wall rigidity if given rapidly; 7-10 times more potent than fentanyl |

## Table 14. Antibiotics for Prevention of Perioperative Infection

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contraindications | Comments |
|---|---|---|---|---|---|---|---|
| Cefotaxime | I.V. | 50 mg/kg | Rapid | q4-6h | Surgical prophylaxis | Cefotaxime hypersensitivity | — |
| Cefoxitin | I.V. | 30-40 mg/kg | Rapid | q4-6h | Surgical prophylaxis | Cephalosporin hypersensitivity | — |
| Metronidazole | I.V. | 7.5-30 mg/kg/d | Rapid | q6h | Surgical prophylaxis | — | — |
| Oxacillin | I.V. | 50 mg/kg | Rapid | q4-6h | Surgical prophylaxis | — | — |
| Penicillin G | I.V. | 50,000-75,000 units/kg | Rapid | q6h | Surgical prophylaxis | — | — |

## Table 15. Vasoactive/Resuscitation Drugs

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Adenosine | I.V. | 0.05 mg/kg increments | Rapid | 3-10 s | Paroxysmal SVT | Atrial flutter, fibrillation; VT | Slows conduction time through AV node; blocks reentry |
| Amiodarone | I.V. | 1 mg/kg aliquots (×5) | Rapid | Long | Refractory VT, VF | — | Class III antiarrhythmic |
| | Infusion | 5-15 mcg/kg/min | Rapid | Ongoing | Refractory VT, VF | — | — |
| Atropine | I.V. | 10-20 mcg/kg | 15-30 s | 30-45 min | Severe bradycardia | — | May be given via ET tube |
| Bretylium | I.V. | 5 mg/kg | 6-20 min | 6-24 h | Refractory VT, VF | — | Class III antiarrhythmic |
| Calcium chloride | I.V. | 10-30 mg/kg | Rapid | Short | Produce cardiac inotropy | — | May be given via ET tube |
| Calcium gluconate | I.V. | 30-100 mg/kg | Rapid | Short | Produce cardiac inotropy | — | — |
| Dobutamine | I.V. | 1-10 mcg/kg/min | 2 min | 10 min | Increase cardiac output | — | Has minimal effect on heart rate |
| Dopamine | Infusion | 1-20 mcg/kg/min | 2-5 min | 10 min | Increase heart rate, contractility, cardiac output | — | Low dose increases renal blood flow; high dose causes vasoconstriction (alpha effect) |
| Epinephrine | I.V. | 10-50 mcg/kg bolus | Immediate | 10 min | Asystole, pulseless arrest | — | May be given via ET tube |
| | Infusion | 0.1-1.0 mcg/kg/min | Rapid | 10 min | Refractory hypotension | — | — |
| Isoproterenol | I.V. | 2 mcg/kg bolus | Rapid | 2-5 min | Severe bradycardia | — | — |
| | Infusion | 0.1-0.5 mcg/kg/min; minimal dose: 0.1 mg | Rapid | 2-5 min | Severe bradycardia | — | — |
| Lidocaine | I.V. | 1.0-1.5 mg/kg bolus in 3 min | Rapid | 20-30 min | Ventricular dysrhythmias | AV, SA block, WPW syndrome | May be given via ET tube 2.0-2.5 times I.V. dose |
| | Infusion | 30-50 mcg/kg/h | Rapid | 1.5 h | — | — | — |
| Milrinone lactate | Infusion | 0.375-1.0 mcg/kg/min | Rapid | 1-2 h | Myocardial dysfunction | Isoproterenol | Loading dose of 50 mcg/kg is required |
| Phenylephrine | I.V. | 5-10 mcg/kg | Immediate | 15-30 min | Shock, severe hypotension, tetralogy of Fallot spells, SVR | — | — |
| Sodium bicarbonate | I.V. | 1 mEq/kg | Rapid | Short | Metabolic acidosis | — | Dilute (1:1 or 1:2) for infants and neonates |
| Tolazoline | I.V. | 1-2 mg/kg followed by 1-2 mg/kg/h | 1-2 min | Up to 60 min | Peripheral asospasm, persistent pulmonary hypertension of newborns | — | Monitor blood pressure; medication may cause hypotension with ephedrine or dopamine, but not with epinephrine |

## Table 16. Cutaneous Analgesics Before Venipuncture/Phlebotomy

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| EMLA (lidocaine-prilocaine cream, AstraZeneca) | Intact skin | 1-20 g by weight | 60-90 min | 30-45 min | Cutaneous analgesia | Risk for methemo-globinemia | Requires occlusive dressing |
| Ferndale L.M.X.4 (lidocaine 4% cream) | Intact skin | 5 g | 30 min | 30 min | Cutaneous analgesia | Allergy to Amide L.A. | May be used with or without occlusive dressing |
| Synera patch (lidocaine-tetracaine, Endo Pharmaceuticals) | Intact skin | 1 patch | 20-30 min | 4 h | Cutaneous analgesia | Allergy to PABA ester L.A. | Gentle heat generation causes vasodilation |



recovery of the train-of-four ratio to 0.9, was found to be less than 2 minutes in a dose-dependent manner. Increasing doses of sugammadex reduced the mean recovery time from 122 minutes (spontaneous recovery) to less than 2 minutes in a dose-dependent manner.[10]

### *Intralipid*

Another drug that has become a welcome addition to many emergency carts in the operating rooms is 20% intralipid, a 20% I.V. fat emulsion. This drug has been shown to shorten the myocardial depression produced by bupivacaine and ropivacaine by displacing the drugs from the myocardial tissue. It is useful in patients who require prolonged resuscitation due to inadvertent local anesthetic toxicity and loss of myocardial activity.[11] In a recent case report of an adult with ropivacaine toxicity, administration of 100 mL, followed by continuous infusion of 10 mL per minute, of 20% intralipid after 10 minutes of unsuccessful cardiopulmonary resuscitation led to spontaneous electrical activity, restoration of cardiac output and complete recovery of the patient.[12]

### *Vasopressin*

Vasopressin by itself or with epinephrine may be superior to epinephrine alone at restoring normal electrical activity in patients in cardiac arrest. A research group in Denver, Colo., has demonstrated this effect in a clinically relevant porcine model of cardiac arrest.[13]

### *Ketamine*

Ketamine is an old drug that is gaining a new reputation as an excellent agent to improve pain therapy in the perioperative period.

### *Sildenafil*

Sildenafil (Viagra, Pfizer) increasingly is being used to treat pulmonary hypertension in children. Long-term therapy of pulmonary hypertension with sildenafil alone or in combination with other agents appears to be safe and well tolerated.[14]

## Conclusion

The practice of medicine is an evolving science. Many of the drugs mentioned in this review are used in children on an off-label basis. The dosage and indications are based on the author's practice and a careful review of the available literature. In some situations, controversy may exist as to the appropriate dose. Caregivers are urged to check current package inserts and standard reference texts for any differences in the indications and dosages or added warnings and precautions.

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## Table 17. Miscellaneous Drugs for Treatment of Other Perioperative Conditions

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Caffeine citrate (Cafcit Injection, Mead Johnson) | I.V. | 10 mg/kg during surgery | 10-20 min | 12-24 h | Postanesthesia apnea in neonates born prematurely | — | Not a substitute for monitoring when indicated |
| Dantrolene sodium (Dantrium I.V., Procter & Gamble) | I.V. | 2-3 mg/kg; repeat ×4 | 5 min | 2-3 h | Malignant hyperthermia | — | May cause dizziness, muscle weakness |
| Desmopressin acetate | I.V. | 0.2-0.4 mcg/kg/dose over 30 min | 10-15 min | 8-12 h | Hemophilia A and von Willebrand's disease | — | May cause headache, nausea, nasal congestion, abdominal cramps |
| | Nasal | 100 mcg/mL solution: 0.05-0.4 mL/d in 3 divided doses | 60 min | 5-18 h | ADH effects in the treatment of diabetes insipidus | — | — |
| Diazepam | I.V. | 0.1-0.3 mg/kg slowly | Rapid | 2-3 h | Status epilepticus | Glaucoma | Monitor for respiratory depression |
| Diphenhydramine | I.V. | 0.25-0.5 mg/kg | Rapid | 4-6 h | Suppression of symptoms of drug allergy, antihistaminic action | — | $H_1$-receptor antagonist, causes sedation |
| Flumazenil | I.V. | 0.01-0.02 mg/kg, maximum dose: 0.2 mg/dose; maximum cumulative dose: 1 mg | 2-3 min | 45-60 min; may repeat q3-5 min | Benzodiazepine antagonist | Status epilepticus; high ICP; chronic benzodiazepine use | — |
| Fosphenytoin (Cerebyx, Pfizer/Eisai Inc.) | I.V. | Loading dose: 15-20 mg/kg PE, slowly for 5-10 min | Rapid | 15 min | Status epilepticus | — | Occasional skin rash. Dosage may be repeated. Very expensive, but less potential to produce side effects than parent compound phenytoin |
| Gabapentin | PO | 5 mg/kg q8h; maximum dose: 300 mg/d | >4 h | 8 h | Seizures, chronic neuropathic pain, bipolar disorders | Renal failure | Specific escalating dosing schedule; may cause somnolence, dizziness, ataxia, tremor, and minor nystagmus |
| Heparin sodium | I.V. | 100 units/kg/dose | Rapid | q4h | Rapid heparinization | — | — |
| | I .V. infusion | 25 units/kg/h | | | | | |
| | Peripheral I.V. | 1-2 mL of 10 units/mL solution | Rapid | q4h | Maintenance of catheter patency | — | — |
| | Central I.V. | 1-2 mL of 100 units/mL solution | Rapid | q24h | Maintenance of catheter patency | — | Aspirate and discard prior to injection of drugs |

*continues on page 121*

## Table 17. Miscellaneous Drugs for Treatment of Other Perioperative Conditions (continued)

| Drug | Route | Dose | Onset | Duration | Pediatric Indications | Contra-indications | Comments |
|---|---|---|---|---|---|---|---|
| Hydroxyzine | I.V., PO | 0.25-0.5 mg/kg | 15-30 min | 4-6 h | Suppression of symptoms of drug allergy, anti-histaminic action | — | $H_1$-receptor antagonist, causes drowsiness and tremors |
| Insulin | I.V. | Loading dose: 0.1 unit/kg. Maintenance: 0.1 unit/kg/h | 30 min | 3-5 h | Diabetic ketoacidosis, hyperglycemia | Hyper-sensitivity to pork | Decrease dose in patients with renal impairment |
| Phenytoin | I.V. | 15-20 mg/kg slowly over 15-20 min | Rapid | 4-12 h | Status epilepticus | — | May cause arrhythmia, bradycardia, hypotension, CV collapse. Dosage may be repeated |
| Protamine sulfate | I.V. | 1 mg for 100 units of heparin | Rapid | 60 min | Heparin reversal | — | Rapid injection can produce hypotension |
| *Drugs To Improve Hemostasis (Antifibrinolytic, Antihemophilic Agents)* | | | | | | | |
| Aminocaproic acid | I.V. bolus and infusion | Bolus: 100 mg/kg; maximum 5 g/30 min. Maintenance: 30 mg/kg/h | 1 h | 12-24 h | Decrease blood loss in patients for anterior/posterior spinal fusion and other procedures when excess blood loss is anticipated | — | Decrease dose in patients with renal impairment |
| Aprotinin (Trasylol, Bayer), 100 mL and 200 mL bottles<br>Note:<br>1 mL=10,000 KIU;<br>1.4 mg/mL= 10,000 KIU/cc | I.V. bolus and infusion | Loading dose: 3 mL/kg over 30 min, followed by 2 mL/kg/h. Maximum dose: 50 mL/h in children >25 kg | 30 min | 3-6 h | Decrease blood loss in patients for anterior/posterior spinal fusion and other procedures when excess blood loss is anticipated | Caution if patient received aprotinin during previous 6 mo; possibility of allergic reaction | Aprotinin is a serine protease inhibitor; a test dose is required 10 min before the loading dose; caution to decrease dosing in patients with renal failure |
| Coagulation factor VIIa, recombinant (NovoSeven, Novo Nordisk) | I.V. | Bolus: 60-90 mcg/kg to be given slowly over 2-5 min; can be repeated in 2 h. Infusion: 20-30 mcg/kg/h for 12 h | 10-20 min | 3-6 h | Episodes of bleeding in patients with hemophilia A or B, when inhibitors to factors VIII or IX are present; clinically, in scenarios that involve excess bleeding | Hypersensitivity to factor VII or any component of the formulation (mouse, hamster, or bovine proteins) | Powder (1.2 mg per vial). Recombinant factor VIIa, a vitamin K–dependent glycoprotein, promotes hemostasis by activating the extrinsic pathway of the coagulation cascade. Precaution: patient should be monitored for signs and symptoms of thrombosis |




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# Patient Guide to Pediatric Anesthesia

Anesthesia is used when a child undergoes surgery or other types of medical procedures, to help him or her stay still and/or to prevent discomfort. The type of anesthesia used depends on several factors, including the type of procedure and the part of the body requiring pain relief.

**Local anesthetics** are used to numb a small area, such as the lips. **Regional anesthesia** is used for a wider area, such as the lower half of the body. **General anesthesia** and **intravenous (I.V.) pain relievers** are used for major procedures.

Anesthesia can be given in several ways. It may be started with an I.V. injection or by letting your child breathe anesthetics through a mask until losing consciousness, so that no injections are given until after your child is sound asleep.

## Risks of Anesthesia

Anesthesia is associated with a number of well-known risks and side effects. The most common side effect of anesthesia is nausea and vomiting after the operation.

The most serious side effects are cardiac arrest and brain damage, but these are rare. The risk is higher in infants with underlying heart defects. The anesthesiologist will constantly monitor your child during the procedure to ensure that the anesthesia does not cause adverse effects.

Studies have shown that certain I.V. and inhaled anesthetic drugs are associated with nervous system changes in animals not undergoing surgery or painful procedures. But it is important to remember that millions of anesthetics have been given to children without evidence of negative effects on the nervous system.

## Q & A

**Q: When will my child wake up?**

A: Some children are fully alert upon arriving in the recovery room, while others may be sleepy for hours after surgery. It is often hard to predict how sedated or sleepy a child will be.

**Q: Why is fasting necessary before surgery?**

A: Anesthesia makes a child very relaxed and sleepy. In this state, the muscles of the stomach and throat, which usually stop food from coming up into the throat and then down into the windpipe and lungs, are relaxed. When food or liquid gets into the lungs from the stomach, the person can develop pneumonia or even die. This is why patients are asked not to eat or drink for a certain length of time before having surgery.

## FOR MORE INFORMATION

Society for Pediatric Anesthesia
**www.pedsanesthesia.org**

American Society of Anesthesiologists
**www.anahq.org**

From the office of _____

Directions/comments _____

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UPDATED 09.07