Rapid sequence intubation (RSI) in children

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INTRODUCTION — Rapid sequence intubation (RSI) describes a sequential process of preparation, sedation, and paralysis to facilitate safe, emergent tracheal intubation. Pharmacologic sedation and paralysis are induced in rapid succession to quickly and effectively perform laryngoscopy and tracheal intubation. At the same time, careful preparation (including preoxygenation) and the use of specific techniques (such as applying cricoid pressure and avoiding positive pressure ventilation) minimize the risks of hypoxia and aspiration.

In the emergency department (ED), RSI is generally the preferred method for emergently intubating patients who have varying levels of consciousness and are presumed to have a full stomach [1].

The success of the procedure depends upon the following:

- Sedation and paralysis eliminate protective airway reflexes and spontaneous respiration. Therefore, difficulties with intubation and/or ventilation must be anticipated and contingency plans for a failed intubation developed.
- The choice of pharmacologic agents for sedation and paralysis is determined based on clinical features that will affect the patient's response to the drug, such as hypotension or preexisting conditions, such as asthma.
- A simple, systematic approach to preparation and execution of the procedure is necessary to perform it quickly and safely.

This topic will discuss evaluation of the patient requiring RSI, as well as choice of pharmacologic agents and the steps involved in performing RSI. Procedures for laryngoscopy and intubation, the difficult pediatric airway, and airway management for adults are discussed elsewhere. (See "Emergency endotracheal intubation in children" and "The difficult pediatric airway" and "Basic airway management in adults" and "Rapid sequence intubation in adults".)

GENERAL CONSIDERATIONS — The sequence of steps in pediatric rapid sequence intubation are: preoxygenation, preparation, administration of pretreatment medications (eg, atropine or lidocaine), sedation and paralysis, airway protection and positioning, endotracheal tube placement with confirmation, and postintubation management (table 1).

Emergent intubations can be performed with or without sedation and paralysis. The vast majority are performed using rapid sequence intubation (RSI), a specific intubation technique that involves sedation and paralysis, with airway protection. This was demonstrated in a large prospective series, including more than 7000 patients, in which 78 percent of intubations were performed using RSI [2].

RSI is generally preferred because it is more successful and safer than intubation without sedation and paralysis for patients with varying levels of consciousness, active protective airway reflexes, and/or a full stomach. The superiority of RSI, as compared with intubation without sedation and paralysis, has been demonstrated by clinical experience and several small retrospective as well as one large prospective observational series in which success rates for intubation were significantly higher and the incidence of adverse events was significantly lower using RSI in the emergency department (ED) [2-8]. In addition, randomized, controlled trials describing intubating conditions (such as ease of laryngoscopy, vocal cord movement, and coughing) for patients intubated in the operating room have consistently reported a significantly higher frequency of excellent intubation conditions with deep sedation plus paralysis (80 to 98 percent) versus that observed with deep sedation alone (0 to 30 percent) [9,10].

RSI can be safely performed by emergency clinicians trained in advanced airway management, including the use of medications for sedation and paralysis. This has been demonstrated in multiple large series of adult patients and several small pediatric series [2,7,8,11,12].

Sedation and paralysis are unnecessary prior to intubation for some patients, such as those who are in cardiac arrest or already deeply comatose.

There are no absolute contraindications to RSI. However, because sedation and paralysis eliminate protective airway reflexes and spontaneous respiration, RSI must be modified for the patient for whom bag-mask ventilation and intubation may be more difficult. An alternative plan that involves assistance from subspecialists (eg, anesthesiologists, otorhinolaryngologists, intensivists) and intubation with sedation, but without paralysis, should be considered for these children.

RAPID OVERVIEW — The goal of rapid sequence intubation (RSI) is to quickly and safely intubate patients using sedation and paralysis. In the majority of situations, RSI, from the decision to intubate to successful intubation, is accomplished in less than 10 minutes (table 1).

A rapid overview can be found in an accompanying table (table 2). It is intended to provide a practical, simplified guide to this process. Each of the steps is discussed in detail in the remainder of the topic.

PREOXYGENATION — Preoxygenation establishes a reservoir of oxygen within the lungs, as well as an oxygen surplus throughout the body. The patient can then tolerate several minutes of apnea without oxygen desaturation, allowing intubation to be safely performed without bag-mask ventilation.

Preoxygenation is particularly important for infants and children. Compared with adults, these young patients have a higher oxygen consumption rate, with lower functional residual capacity and alveolar volume [13,14]. Consequently, oxygen desaturation occurs much more rapidly [13,15]. As an example, arterial oxygen desaturation to 80 percent may occur in a preoxygenated apneic 10 kg infant in less than four minutes, as compared with over eight minutes in a healthy 70 kg adult.

For a child who is breathing spontaneously, adequate preoxygenation can generally be achieved using a nonrebreather mask for a minimum of three minutes. From a practical viewpoint, oxygen should be administered at the highest concentration available as soon as RSI is being considered.

Many children who require intubation are hypoxic, in respiratory failure, or have insufficient respiratory reserve to achieve adequate preoxygenation with spontaneous respirations. In addition, some may be intermittently apneic or may become apneic with administration of the sedative, before receiving the paralytic agent. In these settings, careful bag-mask ventilation with small tidal volumes (while maintaining cricoid pressure) should be performed for several minutes to achieve adequate preoxygenation. Limited evidence suggests that cricoid pressure during bag-mask ventilation is effective for preventing gastric insufflation, reducing the risk of regurgitation and aspiration [16].(See 'Cricoid pressure' below.)

PREPARATION — In the preparation phase of rapid sequence intubation (RSI), a treatment plan for intubation based upon the patient's clinical condition must be quickly developed. This is done as the patient is being preoxygenated.

A rapid review of key aspects of the child's history, as well as a targeted physical examination helps identify conditions that affect the optimal choices of medications for pretreatment, sedation, paralysis, and postintubation management, as well as a contingency plan in the event of a failed intubation. In addition, equipment for monitoring and airway management should be assembled and its function checked.

Assessment — A rapid review of key aspects of the child's history, as well as a targeted physical examination must identify the following conditions:

- Preexisting or current conditions that may be adversely affected by medications or airway manipulation (particularly neuromuscular disease, cardiovascular compromise, increased intracranial pressure, or bronchospasm)
- Clinical features that may make laryngoscopy and/or tracheal intubation difficult

- Conditions that may interfere with bag-mask ventilation

History — The following historical information is useful for selecting medications for RSI, as well as anticipating possible difficulties with airway or ventilation.

- Allergies to medications
- History of or concern for neuromuscular disease and/or renal failure – Succinylcholine can cause a clinically significant rise in serum potassium in patients with neuromuscular disease. Some young children with clinical features, such as hypotonia or developmental delay may have a neuromuscular disorder that has not yet been diagnosed. Renal failure per se is not a contraindication to the use of succinylcholine. However, patients with renal failure may have hyperkalemia, which is a contraindication. (See 'Succinylcholine' below.)
- Family history suggestive of malignant hyperthermia with anesthetics – Use of succinylcholine is absolutely contraindicated in patients who have had or have a family history of malignant hyperthermia.
- Previous intubations or anesthetics – A difficult intubation in the past or an adverse response to an anesthetic must be considered when developing an intubation treatment plan.
- History of asthma – Laryngoscopy may precipitate bronchospasm in children with asthma. In addition, patients with bronchospasm may be difficult to ventilate.
- Noisy breathing, particularly in sleep, suggests some degree of anatomic upper airway obstruction (such as enlarged tonsils or tongue) that may interfere with laryngoscopy or bag-mask ventilation.

Physical examination — Evidence of the following conditions will influence the choice of medications for pretreatment, induction, and paralysis:

- Cardiovascular compromise, such as unexplained tachycardia, poor peripheral perfusion, or hypotension (see "Assessment of perfusion in pediatric resuscitation")
- Increased intracranial pressure, including altered mental status or focal neurologic signs
- Bronchospasm
- Any condition that could result in hyperkalemia, such as an acute crush injury or renal failure

Problems with effective bag-mask ventilation or difficult laryngoscopy and intubation can occur in children with certain physical features. (See "The difficult pediatric airway".) These features include the following (table 3):

- Hoarseness, stridor, drooling, or an upright position of comfort indicates the presence of upper airway obstruction.
- A child with a prominent occiput or misshapen head may be difficult to position optimally for bag-mask ventilation or laryngoscopy.
- Facial anomalies, including burns or other trauma, can make it difficult to obtain an adequate seal for bag-mask ventilation. (See "Basic airway management in children".)
- Small mouth, abnormal palate, large tongue, or a small mandible all suggest that laryngoscopy will be difficult because of decreased space within the oral cavity and mandible.
- Short neck or poor mobility of the neck (congenital anomaly, cervical spine immobilization) may interfere with positioning of the head and neck.

Intubation treatment plan — In addition to choosing medications, an intubation treatment plan should include the following:

- Medications for pretreatment, sedation, paralysis, and postintubation management should be drawn up in weight or length-based doses, doses verified, and syringes carefully labeled.
- A contingency plan for failed intubation must be delineated when a difficult airway is anticipated. (See

"The difficult pediatric airway", section on 'Management'.)

- Roles should be clearly assigned to each healthcare provider, including an assistant to the intubator and someone to apply cricoid pressure. (See 'Cricoid pressure' below.)

Equipment and monitoring — The equipment and monitoring that are necessary for children receiving RSI are the same as for any patient requiring advanced airway management (table 4). Prior to proceeding with rapid sequence intubation, at least one, but preferably two, functioning intravenous lines should be in place. No medications for induction or paralysis should be administered until the equipment, including suction, is assembled and tested for function. In addition, the child must be accurately monitored for oxygen saturation, heart rate, and blood pressure. Once intubation is performed, monitoring should also include end-tidal carbon dioxide (CO_2) detection. (See "Carbon dioxide monitoring (capnography)".)

PRETREATMENT — Manipulation of the airway with a laryngoscope and endotracheal tube results in predictable physiologic responses (increase or decrease in heart rate, increase in intracranial pressure, rise in systemic blood pressure, and increase in airway resistance). Pretreatment with agents that attenuate these responses may be beneficial for conditions, such as brain injury or reactive airways.

Rapid sequence intubation (RSI) becomes more complex and takes longer with the addition of each medication. Consequently, the decision of whether or not to use additional agents must include consideration of the potential benefit to the patient, as well as possible adverse consequences of a prolonged procedure or unanticipated drug responses.

Medications that are usually considered for pretreatment include atropine, lidocaine, opiates, and muscle relaxants for defasciculation.

Atropine — Children, particularly young infants, may have a pronounced vagal response (eg, bradycardia with poor perfusion) to laryngoscopy. In addition, bradycardia and asystole have been reported in children receiving succinylcholine [17]. We therefore suggest the use of atropine with RSI for all children younger than one year, for those less than five years of age receiving succinylcholine, and for children older than five years requiring a second dose of succinylcholine [1,14].

The dose of atropine for pretreatment in RSI is 0.02 mg/kg (maximum 0.5 mg) IV. Based upon limited observational evidence, a minimum dose of 0.1 mg has been suggested to avoid paradoxical bradycardia. However, this effect is most evident in school-aged children and is typically mild. On the other hand, in infants weighing less than 5 kg, this minimum dose can lead to anticholinergic toxicity and some experts advise a weight-based dose as above without a minimum dose. Our approach is to avoid giving a minimum dose less than 0.1 mg. (See "Primary drugs in pediatric resuscitation", section on 'Atropine'.)

Evidence supporting the efficacy of atropine to prevent bradycardia is limited [18]:

- Two small trials in neonates have demonstrated that bradycardia occurred but was significantly less in infants who received atropine prior to laryngoscopy and endotracheal intubation than those who did not (mean heart rate decrease 29 to 36 beats per minute in pretreated neonates versus 52 to 68 beats per minute in controls) [19,20].

- An observational study of 143 children who were intubated in a pediatric emergency department (ED) found six episodes of bradycardia with laryngoscopy. Three of 68 patients pretreated with atropine experienced bradycardia [21]. However, two of these patients were hypoxemic prior to intubation and the remaining patient had an intracranial injury. In addition, succinylcholine was used as the paralytic in only 11 percent of cases.

Atropine is also an anti-sialogogue. However, this effect is not immediate, limiting its usefulness for this indication in RSI.

Atropine may dampen the ability to assess the patient's cardiovascular and neurologic status:

- The effect of atropine on heart rate may persist for several hours and prevent the bradycardic response to hypoxemia [22].

- Atropine dilates the pupils, thus interfering with pupillary response to light as a means to evaluate a change in neurologic status once the patient is paralyzed.

Lidocaine — The use of intravenous lidocaine is optional for RSI in children who may have increased intracranial pressure (ICP) to lessen any additional increase in ICP associated with laryngoscopy and intubation [1,14]. This benefit may be related to suppression of cough and gag reflexes as well as to effects on cerebral perfusion [23].

Evidence regarding the effectiveness of lidocaine for this indication comes from studies in adults and has been inconsistent [24]. Whether or not lidocaine improves upon neuroprotection provided by thiopental or etomidate, is unknown [25]. (See 'Sedative and induction agents' below.) There have been no reports of adverse effects from lidocaine when used to blunt ICP response to airway manipulation [26].

Lidocaine has also been used in adult populations to decrease bronchospasm caused by airway manipulation. Evidence supporting this practice is conflicting [27]. There are no data to support or refute this practice in children.

The dose of lidocaine for pretreatment in RSI is 1.5 mg/kg IV.

Opioids — Pretreatment with opioids is not generally recommended for children [14,25]. Children receiving reliable sedatives, such as thiopental or etomidate rapidly become unconscious (see 'Sedative and induction agents' below). In addition, adverse reactions, particularly hypotension or respiratory depression, can occur when opioids are used in conjunction with other sedating medications. Analgesia with opioids should be provided as part of postintubation care. (See 'Postintubation management' below.)

Opioids (usually fentanyl) are used for pretreatment in adults to attenuate the reflex sympathetic response that occurs with laryngoscopy. This transient increase in heart rate and blood pressure can have an adverse effect for conditions rarely observed in children, such as aortic dissection or aortic aneurysm.

Defasciculating agents — Defasciculating agents (eg, rocuronium or vecuronium at one-tenth of the paralyzing dose) are not routinely recommended for children receiving succinylcholine. (See 'Succinylcholine' below.)

SEDATION AND PARALYSIS — The two essential medications used in rapid sequence intubation (RSI) are a sedative and a paralytic. The sedative agent must always be administered first, followed rapidly by a paralytic, once the child becomes unconscious.

Choice of agent — No ideal sedative exists for every RSI situation. We suggest the use of etomidate or thiopental for the uncomplicated patient undergoing RSI. (See 'Etomidate' below and 'Thiopental' below.)

We suggest the following agents based upon the presence of specific clinical features:

- Hypotension: etomidate or, in patients who are non-catecholamine depleted or in septic shock, ketamine. (See 'Etomidate' below and 'Ketamine' below.)
- Increased ICP: etomidate, thiopental, or, in patients who are hemodynamically stable, propofol. (See 'Etomidate' below and 'Thiopental' below and 'Propofol' below.)
- Hypotensive with head injury: etomidate. (See 'Etomidate' below.)
- Status asthmaticus: ketamine or etomidate. (See 'Ketamine' below and 'Etomidate' below.)
- Status epilepticus: thiopental or midazolam; etomidate (in patients with hypotension). (See 'Thiopental' below and 'Midazolam' below and 'Etomidate' below.)

Sedative and induction agents — The ideal sedative for RSI rapidly induces unconsciousness and has a short duration of action, with minimal side effects (table 5). The presence of the following factors must be considered when choosing a sedative:

- Cardiovascular instability
- Neurologic abnormalities (seizure, increased intracranial pressure)

- Bronchospasm or a history of asthma

Etomidate — Etomidate is an ultrashort-acting, imidazole derivative that produces reliable sedation and induction for RSI without causing significant hemodynamic compromise. It is the sedative administered most frequently in adult patients for RSI in the emergency department (ED), with increasing use for children as well [2,8,28-31]. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Etomidate'.)

The dose of etomidate used in RSI is 0.3 mg/kg IV.

The following evidence supports the use of etomidate for RSI for children in the ED:

- In a prospective series describing children who received etomidate for RSI in a pediatric ED, good intubating conditions (as judged by good vocal cord position, no patient reaction to intubation, and adequate jaw relaxation) were achieved in 68 of 69 patients [32]. Transient hypotension developed after the administration of etomidate in seven patients (five did not require intervention, one had hemorrhagic shock, and one had septic shock).

- A systematic review that included one retrospective pediatric series concluded that, although evidence is limited, etomidate is an effective sedative for RSI in the ED, even in hypovolemic patients or those with limited cardiac reserve [29,33]. A retrospective pediatric series that was not included in the systematic review supports these conclusions [30].

Etomidate reliably decreases intracranial pressure (ICP) and cerebral metabolic rate, suggesting that it has a neuroprotective effect [34-37]. Etomidate also has a protective effect similar to thiopental for generalized seizure activity. However, it may lower seizure threshold in patients with focal seizure disorders and should be used with caution in this situation [38].

Myoclonus has been reported as an adverse effect associated with etomidate. It does not generally interfere with intubation when paralytics are also used [30].

Etomidate inhibits 11-B-hydroxylase, an enzyme important in adrenal steroid production. Transient adrenocortical suppression following a single dose of etomidate has been demonstrated in adults in numerous small randomized trials. This observation may not be clinically significant in patients with normal adrenocortical function. Limited low quality evidence in children suggests that etomidate may adversely affect outcome in patients who already have some degree of adrenocortical suppression, such as those with severe sepsis. The 2007 update to the Clinical Guidelines for Hemodynamic Support of Neonates and Children with Septic Shock from the American College of Critical Care Medicine states that etomidate is no longer recommended to sedate children with septic shock. The 2010 advanced life support recommendations provided by the American Heart Association and the International Liaison Committee on Resuscitation also suggest that etomidate **not** be used routinely in children with septic shock. (See "Septic shock: Rapid recognition and initial resuscitation in children", section on 'Airway and breathing'.)

We suggest the following approach in children with septic shock:

- Ketamine, if available and not contraindicated, is preferable for sedating a child in septic shock prior to rapid sequence intubation. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Ketamine'.)

- Etomidate should not be used routinely in children with septic shock. If etomidate is used, we suggest that, if the patient has septic shock refractory to fluids and vasopressors, a single dose of a corticosteroid, such as hydrocortisone (1 to 2 mg/kg) or dexamethasone (0.1 mg/kg) be given. Hydrocortisone interferes with the short ACTH stimulation test, while dexamethasone does not, so intensivists may prefer the latter if the diagnosis of adrenal insufficiency is unclear. (See "Septic shock: Rapid recognition and initial resuscitation in children", section on 'Airway and breathing'.)

- Emergency clinicians should inform the clinicians assuming care for the patient in the intensive care unit when etomidate has been used for induction.

- Testing to determine the presence of adrenal insufficiency should be performed if possible. (See "Septic shock: Rapid recognition and initial resuscitation in children", section on 'Airway and breathing'.)

- Etomidate should not be used as an infusion or in repeated bolus doses for maintenance of sedation after intubation.
- The use of corticosteroids for the treatment of septic shock in general is reviewed elsewhere. (See "Corticosteroid therapy in septic shock".)

The use of etomidate for RSI in adults with septic shock is discussed in greater detail separately. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Adrenocortical suppression'.)

Thiopental — Thiopental is a short-acting barbiturate with a rapid onset of action that has been used extensively for sedation and induction in RSI. It may provide better intubating conditions than etomidate, as was demonstrated in one large, prospective, observational series of adults and children where successful intubation on the first attempt was more likely with thiopental than with etomidate [28]. However, thiopental causes vasodilatation and myocardial depression, resulting in a decrease in systolic blood pressure. Thus, it should not be used in patients with cardiovascular instability. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Barbiturates'.)

As long as cerebral perfusion pressure is maintained, thiopental provides neuroprotection through reduction in cerebral oxygen consumption and blood flow. It also has anticonvulsant properties, making it a preferred sedative for patients with neurologic injury who are hemodynamically stable.

Finally, thiopental causes histamine release that may contribute to a decrease in systolic blood pressure and be clinically significant in patients with reactive airways.

The dose of thiopental used in RSI is 3 to 5 mg/kg IV. Production of thiopental was discontinued by the sole United States manufacturer in 2011, and it is not available in the United States or Canada [39].

Ketamine — Ketamine is a dissociative anesthetic that is derived from phencyclidine. It produces rapid sedation, amnesia, and analgesia while preserving protective airway reflexes. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Ketamine'.)

Ketamine causes catecholamine release, thus augmenting heart rate and blood pressure in patients who are not catecholamine depleted. It is therefore useful in patients who are hemodynamically unstable.

Catecholamine release associated with ketamine also results in bronchodilatation. It is therefore useful for RSI in patients with bronchospasm [40-43].

Evidence suggesting that ketamine elevates intracranial pressure and is therefore harmful for patients with head injury is weak. On the other hand, ketamine has anticonvulsant properties and may benefit patients with neurologic injury by increasing cerebral perfusion, particularly those who are hypotensive. The use of ketamine for patients with head injury is discussed separately. (See "Sedation or induction agents for rapid sequence intubation in adults", section on 'Elevated intracranial pressure'.)

Initial studies in children indicated ketamine was a potent sialogogue and recommended premedication with atropine [44,45]. However, more recent evidence suggests that excessive salivation is uncommon in doses typically used for rapid sequence intubation (RSI). As an example, in 947 pediatric sedations performed without atropine, significant salivation was reported in approximately 1 percent of patients and was felt to cause airway complications in only one instance [46]. Thus, the use of anticholinergic premedication for ketamine sedation during RSI is **not** routinely necessary.

The dose of ketamine used in RSI is 1 to 2 mg/kg IV.

Propofol — Propofol is a highly lipid soluble, nonbarbiturate sedative-hypnotic that produces general anesthesia. The onset of effect is extremely rapid, with short duration of action.

However, the following characteristics limit its usefulness for RSI for patients who are hemodynamically unstable:

- Vasodilatation and myocardial depression are even more pronounced with propofol than with thiopental.
- The neuroprotective effect of propofol can be offset by a decrease in cerebral perfusion pressure as a

result of decreased arterial pressure.

Formulations of propofol contain egg lecithin, egg yolk phospholipids, and soybean oil. Consequently, children with allergies to egg and/or soybeans should not receive propofol, whenever possible [47].

The dose of propofol used in RSI is 1.5 to 3 mg/kg IV.

Midazolam — Midazolam is a rapid-acting benzodiazepine with potent amnestic and anticonvulsant properties, as well as a short duration of action. It is used commonly for sedation and induction in RSI in children and adults, accounting for nearly 18 percent of sedatives used in one large prospective series [8,28]. (See "Pharmacologic agents for pediatric procedural sedation outside of the operating room", section on 'Midazolam'.)

Time to clinical effect is longer for midazolam than for any of the other sedative agents. Midazolam is frequently underdosed when used for RSI, which may contribute to this observation [48]. However, several reports have noted that it inconsistently induces unconsciousness, even at appropriate doses [23,49].

Midazolam also causes respiratory depression. As a result, patients may develop apnea before they have received a paralytic agent, decreasing the effectiveness of preoxygenation prior to intubation.

Finally, midazolam has a myocardial depressant effect and produces a dose-related reduction in systemic vascular resistance. It should not be used in hemodynamically compromised patients.

The dose of midazolam used for RSI is 0.3 mg/kg IV. This is significantly higher than the dose typically used for procedural sedation.

Paralysis — Paralytic agents provide complete muscle relaxation, which facilitates rapid tracheal intubation. They do not provide sedation, analgesia, or amnesia. As a result, a sedative agent must also be used both for RSI and when paralysis is maintained after intubation. (See 'Sedative and induction agents' above.)

Succinylcholine — Succinylcholine has been used extensively for RSI. It is a depolarizing agent that mimics the effect of acetylcholine at the nicotinic cholinergic receptor, causing continuous depolarization of the muscle membrane. This inhibits repolarization, resulting in paralysis.

Many clinicians consider succinylcholine the ideal paralytic for RSI. This is principally because of its rapid onset of effect (30 to 60 seconds, IV) and short duration of action (four to six minutes, IV). Evidence regarding the relative efficacy of succinylcholine versus other paralytic agents is presented in the next section. (See 'Rocuronium' below.)

There are several serious adverse effects that must be considered in order to use succinylcholine safely. These include the following:

- Bradycardia following the administration of succinylcholine occurs more commonly in children. The risks of bradycardia and, sometimes, asystole are more significant when repeated doses of succinylcholine are administered [1,50]. To avoid these complications, most experts recommend pretreating with atropine for children less than five years of age and for all patients when a second dose is required. Repeated doses of succinylcholine should be avoided whenever possible. (See 'Atropine' above.)

- In certain clinical settings, life-threatening hyperkalemia can occur following the administration of succinylcholine:

- In conditions that result in the upregulation of skeletal muscle acetylcholine receptors (such as motor neuron lesions, muscle injury, muscle disuse, or muscle atrophy), exaggerated potassium efflux from muscle occurs after depolarization, resulting in a life-threatening increase in serum potassium [51]. An increase in the number of receptors usually occurs within two to three days following an injury.

- In patients with myopathies, such as Duchenne or Becker's dystrophy, succinylcholine interacts with the unstable muscle membrane, causing rhabdomyolysis and a rapid increase in plasma potassium. There have been multiple case reports of hyperkalemia and cardiac arrest as a result of this mechanism in patients with undiagnosed myopathies who have received succinylcholine [52,53].

- Malignant hyperthermia can be triggered by succinylcholine. (See "Severe nonexertional hyperthermia (classic heat stroke) in adults".)
- Elevated ICP with the use of succinylcholine has been reported in animal studies and in humans with brain tumors. Although a systematic review found no definitive evidence that succinylcholine causes a rise in ICP in humans with brain injury, the available studies are small and of poor quality [54].
- Elevated intraocular pressure has been described with the use of succinylcholine. This has raised concerns regarding its use for patients with penetrating eye injuries [55]. However, no cases of vitreous extrusion have been reported with the use of succinylcholine for patients with an open globe [56].

As a result of these adverse effects, the use of succinylcholine is **absolutely** contraindicated under the following circumstances [23,52,57]:

- Chronic myopathy or denervating neuromuscular disease
- 48 to 72 hours after burns, a crush injury, or an acute denervating event
- History of malignant hyperthermia
- Preexisting hyperkalemia

Relative contraindications to the use of succinylcholine include:

- Increased intracranial and increased intraocular pressure [23]
- Known pseudocholinesterase deficiency (risk for prolonged duration of action) [57]

The dose of succinylcholine for infants and young children is 2 mg/kg IV, which is higher than that recommended in adults. This is because succinylcholine is rapidly distributed in extracellular water, and young children have a larger relative volume of extracellular fluid [14,57]. For older children, 1 to 1.5 mg/kg is recommended.

Rocuronium — Rocuronium is a nondepolarizing paralytic agent that induces muscle paralysis by competitive antagonism at the nicotinic cholinergic receptor. It has a rapid onset of effect (30 to 60 seconds, IV), but a duration of action that is considerably longer than succinylcholine (30 to 40 minutes) [31].

Rocuronium has none of the adverse effects of succinylcholine, making it a safe and efficacious alternative. As a result, some experts prefer the disadvantage of a longer duration of paralysis with rocuronium to the small risk of using succinylcholine for a child with an undiagnosed contraindication, such as a congenital myopathy or malignant hyperthermia [23].

Despite this, succinylcholine is more likely to provide excellent intubating conditions compared with rocuronium. This was demonstrated in a systematic review in which intubating conditions with succinylcholine were compared with those with rocuronium [58]. Among 26 randomized trials (three of which were in children) using a validated score to assess intubating conditions, excellent conditions were significantly less likely with rocuronium versus succinylcholine (relative risk [RR] 0.87, 95% CI 0.81-0.94). However, there was no difference between succinylcholine and rocuronium for providing clinically acceptable intubating conditions.

The efficacy of rocuronium may be influenced by the dose. Randomized trials in children and adults have demonstrated that intubating conditions are significantly better with 0.9 mg/kg per dose for children and 1 to 1.2 mg/kg per dose for adults, as compared with 0.6 mg/kg per dose [59-61]. In addition, rocuronium at a dose of 1 mg/kg was equivalent to succinylcholine for producing clinically acceptable intubating conditions in these reports. However, the duration of action of rocuronium is longer at the higher dose [58,60].

We suggest using rocuronium, at a dose of 1 mg/kg, as the paralytic agent for RSI when succinylcholine may be contraindicated. Superior intubating conditions are a more important consideration than prolonged duration of action under these circumstances.

Vecuronium — Vecuronium is the nondepolarizing agent from which rocuronium was developed. Like rocuronium, it has a favorable safety profile. However, to achieve as rapid an onset of action as rocuronium, higher doses of vecuronium (eg, 0.15 to 0.2 mg/kg) must be used, which also prolongs paralysis in an unpredictable fashion. In two trials that compared vecuronium with rocuronium for rapid sequence intubation

(RSI), intubating conditions were less optimal in patients who received vecuronium compared to those who received rocuronium [62,63]. For these reasons, its usefulness for RSI is limited. Vecuronium should be used with extreme caution in patients for whom endotracheal intubation is predicted to be difficult.

Pancuronium — Pancuronium is a longer acting nondepolarizing neuromuscular blocking agent that is predominantly used to maintain paralysis after RSI (duration of effect 120 to 150 minutes). Its slower onset of action limits its use in RSI. Pancuronium also has a pronounced vagolytic effect that increases heart rate, blood pressure, and cardiac output.

PROTECTION AND POSITIONING

Protection — Protection during rapid sequence intubation (RSI) refers to protecting the airway by preventing regurgitation of gastric contents and aspiration. This is accomplished with cricoid pressure and by avoiding bag-mask ventilation. In addition, cervical spine protection must be maintained when injury is suspected.

Cricoid pressure — Cricoid pressure is often used in pediatric RSI to reduce gastric insufflation during bag-mask ventilation and to prevent passive regurgitation of gastric contents [64]. In this technique, often referred to as the Sellick maneuver, the thumb and fore or middle finger are used to apply pressure over the anterior neck at the cricoid cartilage to compress the esophagus between the cricoid cartilage and the anterior surface of the C6 vertebral body (figure 1).

When used, cricoid pressure should be applied after the sedative is administered, once the child becomes unconscious. It should be maintained until tracheal tube position is verified.

Cricoid pressure has been considered essential for the protection of the airway during RSI [64]. However, evidence supporting the effectiveness of the technique for preventing regurgitation is limited and conflicting. A systematic review of cricoid pressure noted the following [65]:

- Evidence supporting the technique includes cadaver studies and small case series.
- Case series and retrospective reviews describe failure of cricoid pressure to prevent aspiration.
- Cricoid pressure may be used inconsistently and applied improperly in emergency settings.
- Even healthcare workers who perform the procedure frequently may often do so incorrectly.

Risks associated with the Sellick maneuver include:

- Difficulty viewing the larynx during intubation
- Airway obstruction when ventilation is required
- Movement of the cervical spine in patients with unstable fractures
- Esophageal injury in patients who are actively vomiting

Despite conflicting evidence regarding the effectiveness of cricoid pressure for preventing regurgitation, clinical experience suggests that in most situations, it is not harmful and may be beneficial. We therefore suggest that cricoid pressure be used initially with RSI. However, cricoid pressure should be removed if airway obstruction occurs when ventilation is required or if there is difficulty viewing the larynx.

Bag-mask ventilation — Every effort must be made to avoid bag-mask ventilation (BMV) during RSI, because of the increased risk of vomiting and aspiration that can occur with gastric distention following BMV. However, in patients who cannot be adequately preoxygenated, BMV with small tidal volumes and cricoid pressure is preferable prior to intubating a hypoxic patient. (See 'Preoxygenation' above.)

Positioning — Proper positioning aligns the pharyngeal, tracheal, and oral axes (picture 1).

For children with suspected injury of the cervical spine, positioning must be accomplished without moving the neck. In-line manual stabilization must be maintained. (See "Emergency endotracheal intubation in children", section on 'Positioning' and "Emergency endotracheal intubation in children", section on 'Cervical spine immobilization'.)

PLACEMENT, WITH CONFIRMATION — Onset of paralysis generally occurs within 30 to 60 seconds

following the administration of succinylcholine or rocuronium. Once the child has become apneic, muscle relaxation can be confirmed by testing the jaw for flaccidity. Relaxation is adequate when the jaw can be easily opened. Once adequate muscle relaxation is confirmed, laryngoscopy can be performed with careful attention to proper technique. Oropharyngeal injury can be minimized, while effectively exposing the glottic aperture. After the tracheal tube has been placed and stylet removed, tube placement must be confirmed. (See "Emergency endotracheal intubation in children", section on 'Laryngoscopy' and "Emergency endotracheal intubation in children", section on 'Confirming tube position'.)

POSTINTUBATION MANAGEMENT — Following placement and confirmation, the tracheal tube should be appropriately secured and a chest radiograph obtained to document proper placement and evaluate pulmonary status. (See "Emergency endotracheal intubation in children", section on 'Post-intubation care'.)

Ongoing sedation and analgesia, generally with paralysis, is essential for as long as the patient requires advanced airway support. Hemodynamic considerations generally dictate which pharmacologic agents should be used. A benzodiazepine (such as lorazepam) is often used in combination with pancuronium or vecuronium. (See 'Sedative and induction agents' above.)

For children who are hemodynamically stable, opioid analgesia (such as fentanyl or morphine) should be added.

SUMMARY AND RECOMMENDATIONS

- Rapid sequence intubation (RSI) provides optimal conditions for emergent intubation. We recommend that clinicians who are trained in tracheal intubation use RSI for most children who require emergent intubation who are not in cardiac arrest or already deeply comatose (**Grade 1B**). A simple, systematic approach to preparation and execution of the procedure is necessary in order to perform RSI quickly and safely (table 2). (See 'General considerations' above.)

- RSI must be modified for the patient for whom bag-mask ventilation and intubation may be more difficult. An alternative plan that involves assistance from subspecialists (anesthesiologists, otorhinolaryngologists, intensivists) and intubation with sedation, but without paralysis, should be considered for these patients. (See "The difficult pediatric airway", section on 'Identification of the difficult pediatric airway' and "The difficult pediatric airway", section on 'Management'.)

- The sequential steps involved in RSI are summarized below. The factors underlying the decision to intubate, as well as procedures for laryngoscopy and intubation are discussed elsewhere. (See "Emergency endotracheal intubation in children".)

- **Preoxygenation** – Preoxygenation is a critical step in RSI, particularly for children. Oxygen should be administered at the highest concentration available as soon as RSI is being considered. Children who have insufficient respiratory reserve or who are experiencing apnea may require careful bag-mask ventilation with small tidal volumes (while maintaining cricoid pressure) to achieve adequate preoxygenation. (See 'Preoxygenation' above.)

- **Preparation** – In the preparation phase of RSI, a rapid review of key aspects of the child's history, as well as a targeted physical examination, helps identify conditions that affect the optimal choices of medications. In addition, equipment for monitoring and airway management should be assembled and its function checked. This is done as the patient is being preoxygenated (table 3 and table 4). (See 'Preparation' above.)

- **Pretreatment** – Medications used for pretreatment attenuate physiologic responses to laryngoscopy and tracheal intubation. The principal adverse responses in children are bradycardia and increased intracranial pressure (ICP). (See 'Pretreatment' above.)

    - We suggest using atropine to prevent bradycardia for all **children** younger than one year and for children less than five years of age who are receiving succinylcholine for paralysis (**Grade 2C**). Atropine should also be given to children older than five years who are receiving a second dose of succinylcholine. However, repeated doses of succinylcholine should be avoided whenever possible. The dose of atropine for pretreatment in RSI is 0.02 mg/kg (maximum 0.5 mg) IV. Whether a minimum dose of 0.1 mg should be used to avoid paradoxical bradycardia is unclear and some

experts advise to strictly use weight-based dosing in neonates. Our approach is to avoid an atropine dose below 0.1 mg. (See 'Atropine' above.)

- The use of intravenous lidocaine is optional for RSI in children with possible increased ICP. Evidence regarding the effectiveness of lidocaine for this indication comes from studies in adults and has been inconsistent. Whether or not lidocaine improves upon neuroprotection provided by thiopental or etomidate, is unknown. The dose of lidocaine for pretreatment in RSI is 1.5 mg/kg IV. (See 'Lidocaine' above.)

- **Sedation** – Two essential medications used in RSI are a sedative and a paralytic. The sedative agent must always be administered first, followed rapidly by a paralytic, once the child becomes unconscious. Important issues that determine the optimal agents for sedation include hemodynamic instability, need for neuroprotection, and history of bronchospasm (table 5). (See 'Sedative and induction agents' above.) The following are our recommendations for the preferred sedative agent for any given patient based on the presence or absence of these clinical features:

  - For hemodynamically **stable** children, we suggest using thiopental as the sedative agent (**Grade 2C**). We recognize that thiopental may not be commercially available, and others may choose etomidate because of concern for unanticipated hypotension with thiopental in patients who initially appear stable. (See 'Thiopental' above.) The dose of etomidate used in RSI is 0.3 mg/kg IV. The dose of thiopental used in RSI is 3 to 5 mg/kg IV.

  - For children with suspected increased ICP who are hemodynamically stable, we suggest using etomidate or thiopental as the sedative agent (**Grade 2C**). For children with suspected increased ICP who are hemodynamically unstable, we suggest using etomidate (**Grade 2C**).

  - For children with bronchospasm, septic shock, or a history of asthma, we suggest administering ketamine for sedation (**Grade 2C**). This can be given to both hemodynamically stable and unstable patients. The dose of ketamine used in RSI is 1 to 2 mg/kg IV. (See 'Ketamine' above.)

  - For hemodynamically **unstable** children in septic shock, we suggest NOT using etomidate as a sedative agent (**Grade 2C**). Ketamine, if available and not contraindicated, is preferable. For hemodynamically unstable children with septic shock who do receive etomidate for induction for RSI, we suggest that they also receive a single dose of a corticosteroid, such as hydrocortisone (1 to 2 mg/kg) or dexamethasone (0.1 mg/kg) (**Grade 2C**). Etomidate should not be used as an infusion or in repeated bolus doses for maintenance of sedation after intubation. (See 'Etomidate' above.)

  - For children in status epilepticus, we suggest using thiopental or midazolam for sedation (**Grade 2C**). For the patient in status epilepticus who is hemodynamically unstable, we suggest using etomidate (**Grade 2C**). The dose of midazolam used for RSI is 0.3 mg/kg IV.

- **Paralysis** – Paralytic agents provide complete muscle relaxation, which facilitates laryngoscopy and rapid tracheal intubation. They do not provide sedation, analgesia, or amnesia. The following are our recommendations concerning the optimal paralytic agent (see 'Paralysis' above):

  - Unless contraindicated, we suggest using succinylcholine for paralysis for children undergoing RSI (**Grade 2B**). The dose of succinylcholine for infants and young children is 2 mg/kg IV. Older children should receive 1 to 1.5 mg/kg. However, a significant number of absolute and relative contraindications exist. (See 'Succinylcholine' above.)

  - When succinylcholine cannot be used, we recommend using rocuronium as a paralytic agent for RSI in children (**Grade 1B**). We suggest using rocuronium at a dose of 1 mg/kg (**Grade 2B**). Intubating conditions with this dose of rocuronium are superior to those using rocuronium at a lower dose. (See 'Rocuronium' above.)

- **Protection and positioning** – Cricoid pressure and avoiding bag-mask ventilation may protect the airway by preventing regurgitation of gastric contents and aspiration. We suggest that cricoid pressure be used initially with RSI (**Grade 2C**). However, cricoid pressure should be removed if there is difficulty viewing

the larynx or airway obstruction occurs when ventilation is required. Cricoid pressure should be applied after administration of the sedative, as soon as the child becomes unconscious. It should not be released until tracheal tube placement is confirmed. Bag-mask ventilation (using small tidal volumes and cricoid pressure) should be performed only when required to maintain oxygenation. (See 'Protection and positioning' above.)

- **Placement, with confirmation** – Laryngoscopy and tracheal intubation may be performed once adequate muscle relaxation is confirmed. Tracheal placement should be confirmed by primary methods (such as auscultation for breath sounds over lung fields and stomach, the appearance of mist inside the tracheal tube, and symmetric chest rise with positive pressure ventilation) as well as confirmation with detection of end-tidal carbon dioxide. (See 'Placement, with confirmation' above and "Carbon dioxide monitoring (capnography)".)

- **Postintubation management** – Following placement and confirmation, the tracheal tube should be appropriately secured. A chest radiograph should also be obtained to document proper placement and evaluate pulmonary status. Ongoing sedation, analgesia (eg, fentanyl or, if hemodynamically stable, morphine), and paralysis are typically required. (See 'Postintubation management' above.)

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Topic 6390 Version 17.0

GRAPHICS

Summary: The Seven Ps of rapid sequence intubation

Action	Time
Preparation	10 minutes before intubation
Preoxygenation	5 minutes before intubation
Pretreatment	3 minutes before intubation
Paralysis with induction	Induction
Protection	30 seconds after induction
Placement (Intubation)	45 seconds after induction
Post-intubation management	60 seconds after induction

Graphic 77060 Version 3.0

Rapid overview of rapid sequence intubation in children

Preoxygenation
Begin preoxygenation as soon as the decision to intubate is considered.
Administer oxygen at the highest concentration available.
Preparation
Identify conditions that will affect choice of medications.
Identify conditions that will predict difficult intubation or bag-mask ventilation.
Assemble equipment and check for function.
Develop contingency plan for failed intubation.
Pretreatment
Atropine: All children ≤1 year, children <5 years receiving succinycholine, and older children receiving a second dose of succinylcholine. Dose: 0.02 mg/kg IV (maximum single dose 0.5 mg, minimum 0.1 mg; if no IV access, can be given IM).
Lidocaine: Optional for increased intracranial pressure. Dose: 1.5 mg/kg IV (maximum dose 100 mg). Give two to three minutes before intubation.
Sedation
Etomidate: Safe with hemodynamic instability, neuroprotective, transient adrenal corticosuppression. Do **not** use routinely in patients with septic shock. Dose: 0.3 mg/kg IV.
Ketamine: Safe with hemodynamic instability if patient is not catecholamine depleted. Use in patients with bronchospasm and septic shock. Use with caution in patients with increased intracranial pressure. Dose: 1 to 2 mg/kg IV. (If no IV access, can be given IM dose: 3 to 7 mg/kg).
Midazolam: Time to clinical effect is longer, inconsistently induces unconsciousness. May cause hemodynamic instability at doses required for sedation. Dose: 0.2 to 0.3 mg/kg IV (maximum dose 2 mg, onset of effect requires two to three minutes).
Thiopental: Neuroprotective. Do not use with hemodynamic instability. Dose: 3 to 5 mg/kg IV.*
Paralytic
Succinycholine: Do not use with chronic myopathy or denervating neuromuscular disease; 48 to 72 hours after burn, crush, or denervating injury; malignant hyperthermia; or pre-exisiting hyperkalemia. Dose: infants and young children: 2 mg/kg IV, older children: 1 to 1.5 mg/kg IV. (If IV access unobtainable, can be given IM, dose: 3 to 5 mg/kg).
Rocuronium: Use for children with contraindication for succinylcholine. Suggested dose: 1 mg/kg IV (range 0.6 to 1.2 mg/kg).¶
Protection and positioning
Maintain manual cervical spine immobilization during intubation in the trauma patient.
If cervical spine injury is not potentially present, put the patient in the "sniffing position" (ie, head forward so that the external auditory canal is anterior to the shoulder and the nose and mouth point to the ceiling). Apply cricoid pressure when the child is unconscious. Remove cricoid pressure if it causes airway obstruction or difficulty viewing the larynx.
If used, maintain cricoid pressure until tracheal tube position is verified.

Positioning, with placement
Confirm tracheal tube placement with end-tidal CO_2 detection and auscultation.
Postintubation management
Chest radiograph for tracheal tube placement; provide ongoing sedation (eg, midazolam), analgesia (eg, fentanyl 1 mcg per kg), and, if indicated, paralysis.Δ

If IV access unobtainable, intraosseous administration of drugs listed is feasible (no data for ketamine).

* Not available in the United States and Canada.
¶ Vecuronium may be used in children with contraindications to succinylcholine and when rocuronium is not available. Suggested dose for RSI: 0.15 to 0.2 mg/kg. Patients may experience prolonged and unpredictable duration of paralysis at this dose.
Δ If decompensation after successful intubation use DOPE mnemonic to find cause:

- D: Dislodgement of the tube (right mainstem or esophageal)
- O: Obstruction of tube
- P: Pneumothorax
- E: Equipment failure (ventilator malfunction, oxygen disconnected or not on).

Graphic 51456 Version 19.0

Physical assessment to identify signs of a difficult airway in children

Difficulty	Signs
Positioning	Prominent or misshapen occiput, short neck, poor neck mobility
Bag-mask ventilation	Facial anomalies, facial trauma (including burns)
Laryngoscopy	Small mouth, small mandible, abnormal palate, large tongue
Intubation	Signs of upper airway obstruction (hoarseness, stridor, drooling, upright position of comfort)

Graphic 71326 Version 2.0

Airway equipment for pediatric patients

Supplemental oxygen
Nasal cannulae (infant, child, and adult)
Clear oxygen masks (standard and nonrebreathing - infant, child, and adult)
Suction
Suction catheters (6 through 16 French)
Yankauer suction tip (two sizes)
Bag-mask ventilation
Masks (neonate, infant, child, adult)
Self-inflating resuscitator bag (450 and 1000 mL)
Artificial airways
Oropharyngeal airways (sizes 0 through 5)
Nasopharyngeal airways (12 through 30 French)
Intubation equipment
Endotracheal tubes (uncuffed and cuffed, 2.5 through 8.0 mm internal diameter)
Stylets (infant, pediatric, and adult)
Laryngoscope handle (pediatric and adult)
Laryngoscope blades: straight (sizes 0, 1, 2, and 1.5 Wis-Hipple) and curved (sizes 2 and 3)
Rescue airway devices
Laryngeal mask airway (sizes 1, 1.5, 2, 2.5, 3, 4, and 5)
Combitube (37 and 41 French)
Miscellaneous
End-tidal CO2 detector
Magill forceps (pediatric and adult)
Bulb suction

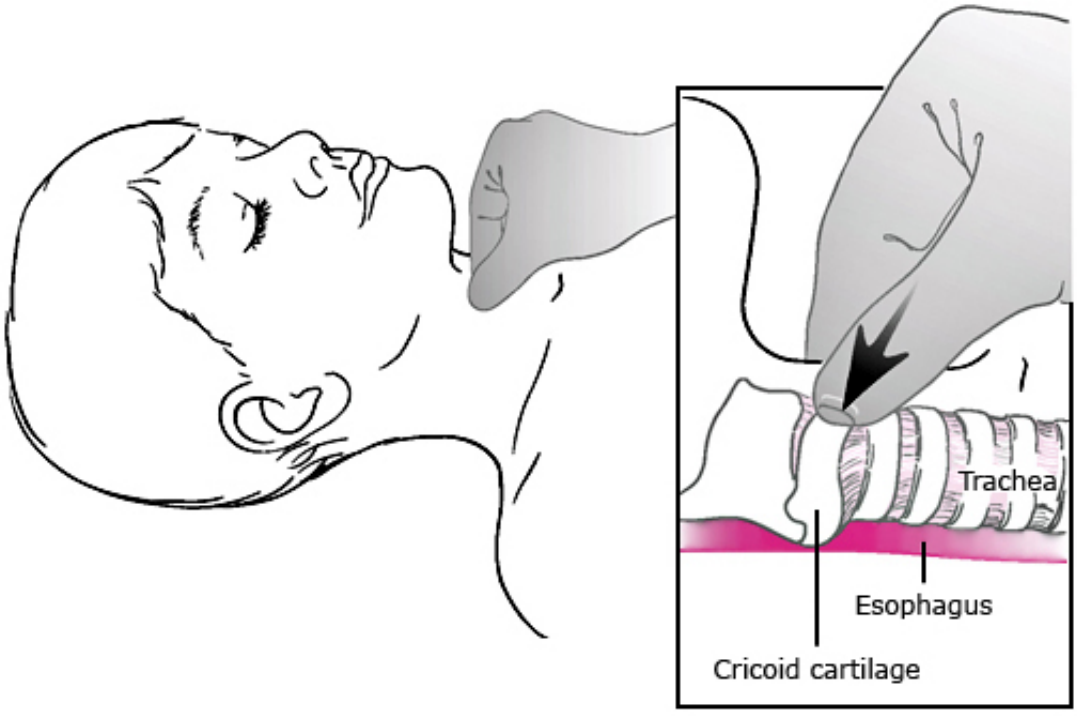
Graphic 71484 Version 2.0

Rapid sequence intubation induction agents

Drug name	Class	Benefits	Contraindications	Notes	Dos
Etomidate	Imidazole derivative	Excellent sedation with little hypotension	Known to suppress adrenal cortisol production	Use cautiously if patient has sepsis; initial dose of glucocorticoid may be needed	0.3 mg/k
Ketamine	Phencyclidine derivative, dissociative anesthetic	Stimulates catecholamine release Bronchodilation	Use in patients with elevated ICP or elevated blood pressure is controversial	May be an excellent induction agent for patients with bronchospasm, septic shock, **AND** hemodynamic compromise	1 to 2 mg/k
Midazolam	Benzodiazepines	Potent dose-related amnesic properties	Dose-related myocardial depression can result in hypotension	Frequently underdosed	0.2 to 0.3 mg/k
Propofol	Alkylphenol derivative	Bronchodilation	No absolute contraindications Dose-related hypotension		1.5 to 3 mg/k
Thiopental sodium	Ultrashort-acting barbiturate	Cerebroprotective and anti-convulsive properties	Potent venodilator and myocardial depressant; can cause hypotension Relatively contraindicated in reactive airway disease due to histamine release Acute intermittent and variegate porphyrias	May not be commercially available	3 to 5 mg/k
Methohexital	Barbiturate	Cerebroprotective	Acute intermittent and variegate porphyrias	Rarely used	1 to 3 mg/k

Graphic 64272 Version 8.0

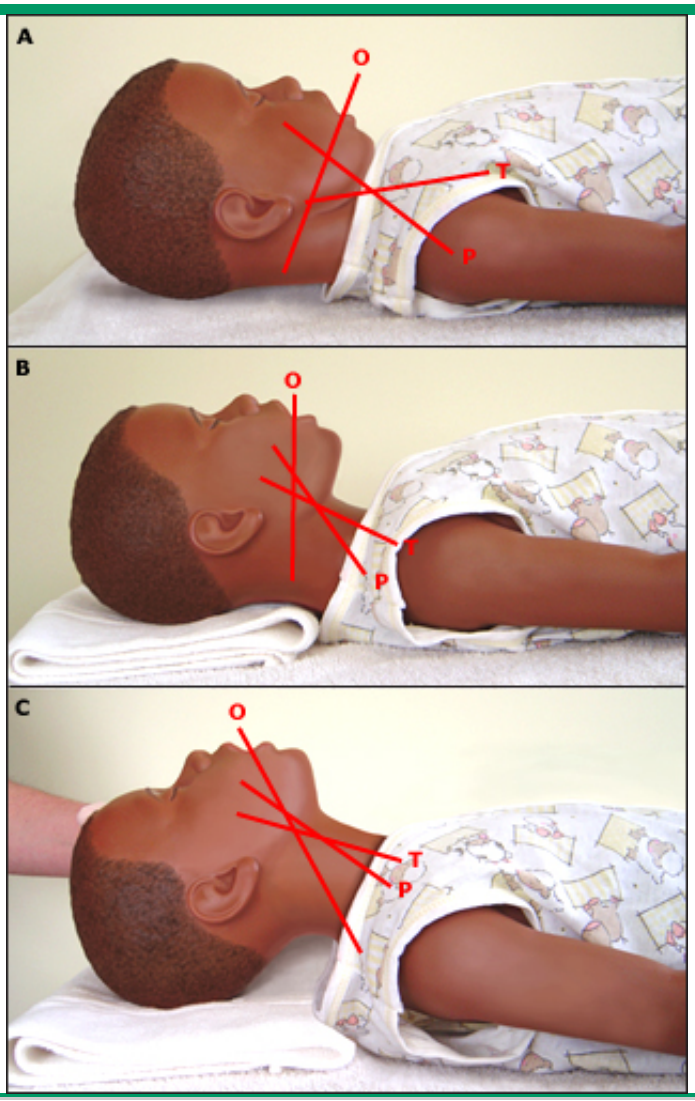
Cricoid pressure (Sellick's maneuver)



Cricoid pressure (Sellick maneuver). Posterior displacement of the airway cartilages occludes the compliant esophagus. In infants and young children, the tracheal cartilage is also very compliant, and excessive force while applying cricoid pressure may impair airway patency.

Graphic 71800 Version 8.0

Proper positioning for ventilation and intubation for children older than two years of age



A) The oral (O), tracheal (T), and pharyngeal (P) axes are in divergent planes. B) A towel under the occiput brings the external auditory canal anterior to the shoulder, aligning the T and P axes. C) The extension of the head on the neck, with the mouth and nose facing the ceiling, aligns the O axis with the T and P axes.

Graphic 69636 Version 5.0

Disclosures

Disclosures: **Dewesh Agrawal, MD** Nothing to disclose. **Susan B Torrey, MD** Nothing to disclose. **James F Wiley, II, MD, MPH** Nothing to disclose.

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