Rapid sequence intubation in adults

INTRODUCTION — The first task of any clinician managing an acutely unstable patient is to secure the airway. In most circumstances, emergency clinicians use rapid sequence intubation (RSI) to accomplish this task. RSI incorporates a rapidly acting sedative (ie, induction) agent and a neuromuscular blocking (ie, paralytic) agent to create optimal intubating conditions and enable rapid control of the airway. RSI presupposes the patient is at risk for aspiration of stomach contents and incorporates medications and techniques to minimize this risk. Use of RSI also helps to mitigate the potential adverse effects of airway manipulation.

This topic review will discuss the central concepts and techniques needed to perform rapid sequence intubation in adults. Discussions of RSI in children, the medications used for RSI, and other subjects related to emergency airway management are reviewed elsewhere.

DEFINITION — Rapid sequence intubation (RSI) is the virtually simultaneous administration of a sedative and a neuromuscular blocking (paralytic) agent to render a patient rapidly unconscious and flaccid in order to facilitate emergent endotracheal intubation and to minimize the risk of aspiration. Preoxygenation is required to permit a longer period of apnea without clinically significant oxygen desaturation. Bag-mask ventilation is avoided during the interval between drug administration and endotracheal tube placement, thereby minimizing gastric insufflation and reducing the risk of aspiration.

Indications — Rapid sequence intubation (RSI) is the standard of care in emergency airway management for intubations not anticipated to be difficult. Multiple large prospective observational studies confirm that the implementation of RSI has led to improved success and decreased complication rates for emergency intubations.

Contraindications — Contraindications to rapid sequence intubation (RSI) are relative. Circumstances exist where neuromuscular blockade is undesirable due to the high likelihood of intubation or mechanical ventilation failure. Depending on clinical circumstances, particular sedative or neuromuscular blocking agents may be relatively contraindicated, due to the risk of potential side effects.

DESCRIPTION OF THE TECHNIQUE — Rapid sequence intubation (RSI) depends on preparation and detailed considerations at multiple steps. The "Seven P's of RSI" is a mnemonic that outlines these key steps:

- Preparation
- Preoxygenation
- Pretreatment
- Paralysis with induction
- Protection and positioning
- Placement with proof
- Postintubation management

Preparation — Preparation includes assessing the patient's airway, developing an airway management plan, and assembling necessary equipment and medications.

Once the need for intubation is determined, the clinician assesses the patient for anatomic features or clinical findings that indicate the patient may be difficult to intubate or to ventilate using a bag-mask. Although the presence of markers for difficult intubation or difficult bag-mask ventilation is
not an absolute contraindication to RSI, if such features are identified, alternatives to rapid sequence intubation (RSI) may be needed. Alternatives include an "awake technique" in which the patient is lightly to moderately sedated, and intubated using topical anesthesia, but is not induced and paralyzed.

Prior to proceeding with RSI, at least one, but preferably two, functioning intravenous line should be in place, and cardiac, pulse oximetry, and blood pressure monitors should be in place. The patient should be in an appropriate area within the emergency department where necessary airway and resuscitation equipment are available. The airway manager should have easy access to the head of the bed, and should adjust the height of the bed and position of the patient to facilitate intubation.

The airway manager verifies that endotracheal tubes of appropriate sizes are available and their cuffs are free of leaks. A stylette is placed in the tube. If a conventional laryngoscope is to be used, its light must be working and both curved and straight blades of different sizes (generally Macintosh and Miller sizes 3 and 4) available. Suction devices are checked and ready for immediate use. A bag-mask and both oral and nasal pharyngeal airways should be at the bedside.

The clinician selects the induction and paralytic agents (and pretreatment medications if desired) to be used and determines the doses. Allergies and potential contraindications should be considered carefully. The medications to be used are drawn up into labeled syringes.

A critical and often overlooked part of this initial phase of RSI is preparation for unanticipated difficulty. An assessment of airway difficulty should be performed before the decision is made to proceed with RSI. Even if there are no indicators of difficult intubation identified and the intubation appears likely to be routine, the airway manager must have a backup plan to manage unanticipated problems with intubation or bag-mask ventilation. Backup plans will vary with the clinical situation, the availability of devices, and the training of the provider. Equipment necessary to implement the backup plan should be at the bedside.

**Preoxygenation** — Any patient who may require endotracheal intubation is immediately given high flow oxygen at the highest possible concentration. Giving oxygen in anticipation of rapid sequence intubation (RSI) has several important effects. In addition to improving the patient's oxyhemoglobin saturation, high flow oxygen displaces nitrogen in the patient's lungs. "Washing out" the nitrogen and replacing it with oxygen converts the lung's functional residual capacity into an oxygen reservoir. Preoxygenation also increases oxygen stores in the blood and tissues. The combined effect is to enable patients to tolerate a longer period of apnea without oxygen desaturation. Preoxygenation is essential if clinicians are to avoid the need for assisted ventilations interposed between paralysis and placement of the endotracheal tube.

Researchers have characterized the expected time to desaturation after apnea is induced in properly preoxygenated patients of various ages and comorbid conditions. A healthy 70 kg adult can maintain oxygen saturation above 90 percent for eight minutes. Young children typically fall below the 90 percent threshold in less than four minutes. The oxygen saturation of adults with severe illness or obesity, and pregnant women nearing the end of their third trimester, falls below 90 percent in less than three minutes. The important concept is that preoxygenation provides a longer period before clinically significant desaturation, regardless of the patient's condition. The duration of this period varies greatly, depending on patient attributes, and continuous monitoring of oxyhemoglobin saturation by pulse oximetry is essential.

Clinicians may need to adjust the method for providing preoxygenation according to clinical circumstances. If time allows, preoxygenation is traditionally achieved by high flow oxygen via a nonrebreather facemask applied for three to five minutes before RSI. A longer period of preoxygenation in critically ill patients is unlikely to provide significant benefit.
Nitrogen washout can also be achieved by having the patient take eight vital capacity (ie, maximal) breaths. One small randomized trial found that the oxygen reservoir can be supplemented by passive diffusion during the apneic period of RSI with the application of oxygen via nasal catheter. Providing oxygen via noninvasive positive pressure ventilation may enhance preoxygenation in obese patients.

**Pretreatment** — Pretreatment is the administration of medications prior to the induction phase of rapid sequence intubation (RSI) for the purpose of mitigating adverse effects associated with endotracheal intubation. The drugs used for pretreatment vary with clinical circumstances. Pretreatment agents for RSI are discussed in detail separately.

**Paralysis with induction** — The concept of rapid sequence intubation (RSI) is based on the virtually simultaneous intravenous administration of a rapidly acting induction agent and a neuromuscular blocking agent (paralytic). Agent selection and dosing are aimed at producing a state of deep sedation and muscular relaxation quickly. RSI does NOT involve titration of either agent to reach this state. The dose of each agent is precalculated to achieve the desired effect. Onset of action after administration is variable depending on the agent chosen, but the goal is to achieve intubation level paralysis and sedation 45 to 60 seconds after the drugs are given by IV push.

Induction agents — The ideal RSI induction agent acts quickly to provide a deep state of unconsciousness, as well as analgesia, with limited side effects. No available agent meets this ideal standard. Drugs that have been used as induction agents include etomidate, ketamine, midazolam, propofol, and short-acting barbiturates (eg, thiopental). The induction agents used for RSI are discussed in detail separately. A summary table of induction agents is provided (below).

Neuromuscular blocking agents — The use of a neuromuscular blocking agent (NMBA) to produce rapid paralysis comprises the cornerstone of rapid sequence intubation (RSI). Neuromuscular blocking agents do NOT provide analgesia or sedation. In the context of RSI, they are used immediately following an induction agent. The NMBAs used for RSI are discussed in detail separately.

**Protection and positioning** — This phase of rapid sequence intubation (RSI) refers to protecting the airway against aspiration prior to placement of the endotracheal tube by avoiding bag-mask ventilation and applying cricoid pressure (Sellick's maneuver). Bag-mask ventilation is unnecessary if the patient has been successfully preoxygenated.

Furthermore, ventilation interposed between paralysis and intubation creates a potential hazard if stomach insufflation results in regurgitation and aspiration. Provided oxygen saturation remains above 90 percent, bag-mask ventilation is unnecessary, even between laryngoscopy attempts. If the patient's saturation percentage falls below 90, or is unknown, clinicians provide ventilatory support using a bag-mask, while maintaining cricoid pressure.

Sellick originally described the concept of cricoid pressure as a method to prevent passive regurgitation. A systematic review questions the technique's effectiveness and we consider it optional during RSI. Sellick's maneuver is performed using the thumb and index or middle finger to apply firm downward pressure on the cricoid cartilage thereby compressing the esophagus between the cricoid cartilage and the anterior surface of the vertebral body. A common error is to apply pressure to the thyroid cartilage (Adam's apple).

While in practice cricoid pressure is maintained by an assistant, the airway manager directs the application and duration of force being applied. When used, cricoid pressure is applied immediately following induction and maintained until adequate tube placement has been confirmed. Sometimes Sellick's maneuver may obscure the glottic view, impede passage of the endotracheal tube, or
prevent adequate ventilation (when ventilation is necessary). If so, the intubator should have the assistant reduce or remove cricoid pressure.

Although Sellick's maneuver may reduce gastric insufflation during bag-mask ventilation, evidence that cricoid pressure reduces the incidence of aspiration of gastric contents is scant and consists primarily of observational clinical studies and experimental data. Several studies suggest it may contribute to airway obstruction and difficulty intubating in some cases. Until more definitive literature is published, we suggest that the use of Sellick's maneuver during RSI and bag-mask ventilation be considered optional.

A systematic review of cricoid pressure studies noted the following:

- Case series and retrospective reviews describe both the success and failure of cricoid pressure to prevent aspiration.
- Cricoid pressure is often used inconsistently and applied improperly in all airway management settings.
- Radiographic studies suggest that cricoid pressure often results in lateral displacement of the esophagus rather than occlusion.
- Cricoid pressure may impair the function of the lower esophageal sphincter.
- Possible risks from cricoid pressure include movement of unstable cervical spine fractures and esophageal injury.

**Placement with proof** — After flaccidity is achieved, assessed by masseter muscle tone (ie, laxity of the jaw with no resistance to mouth opening), laryngoscopy can be performed. The time to muscular relaxation will vary depending on the neuromuscular blocking agent used. When used with an appropriate induction agent, **succinylcholine** generally produces excellent intubating conditions within 45 seconds, compared to **rocuronium**, which requires 60 seconds. The goal of laryngoscopy is direct visualization of the glottic aperture. Once the glottis is visualized, the clinician places the endotracheal tube between the cords, inflates the cuff, withdraws the stylette, and confirms placement.

Confirmation of proper endotracheal tube (ETT) placement is crucial; unrecognized esophageal intubation leads to devastating complications. End-tidal CO2 (EtCO2) determination (either colorimetric or quantitative) is the most accurate means of confirming ETT placement in most circumstances and we recommend it be used with every intubation.

Published reports and clinical experience make clear that clinicians cannot rely on clinical indicators alone to confirm ETT placement. Such signs as visualization of the ETT through the cords, misting of the tube with ventilation, and auscultation of breath sounds over the lung fields are insufficient means to confirm tracheal placement.

One caveat to the accuracy of EtCO2 detectors is the cardiac arrest patient. Such patients may not generate CO2, making the absence of CO2 detection meaningless. When CO2 is detected in the cardiac arrest patient, however, and persists for six breaths, the ETT is in the airway. EtCO2 detection must be interpreted in conjunction with the ETT's insertion depth. An ETT placed in the mainstem bronchus (too deep) or supraglottic region (too shallow) can generate an EtCO2 measurement identical to that of a properly placed ETT.

Alternative methods of determining proper endotracheal tube placement have been used successfully. One example is the suction method. This approach uses syringe or bulb suction devices to distinguish between the trachea (which is rigid and allows a free flow of air into the
device) and the esophagus (which is collapsible, permitting little airflow when suction is applied). These devices can be useful (eg, in cardiac arrest) but are not infallible.

There is some evidence that an endotracheal tube introducer (Eschmann introducer) may be useful as an endotracheal tube confirmation device. After passing the introducer through the ETT, the clinician can feel the introducer tip move over the tracheal rings. The clinician will also feel an abrupt hold-up during advancement of the introducer as its tip comes to rest within a bronchus. No such hold-up is encountered if the ETT has been misplaced into the esophagus, as the introducer will pass easily without significant resistance. Fiberoptic visualization of the tracheal rings and carina may also be used to confirm tracheal placement.

A single-view chest x-ray is only useful to determine depth of placement (eg, tracheal versus right mainstem). It is not useful for distinguishing endotracheal from esophageal intubation.

**Postintubation management** — Rapid sequence intubation (RSI) remains incomplete until the properly placed endotracheal tube is secured. Several techniques are commonly used to secure the tube, including taping, tying, and using proprietary tube-holders. There is some evidence to suggest that a tube stabilizing device may be better tolerated than taping for long-term management. The technique employed for ED airway management should be readily available, easy to apply, and secure.

A post procedural chest x-ray is obtained to confirm depth of tube placement and to evaluate for evidence of barotrauma as a consequence of positive pressure ventilation.

Hypotension can occur soon after intubation, often as a result of reduced venous return, because of increased intrathoracic pressure from mechanical ventilation. Lingering effects of the induction agent may contribute. While diminished venous return and sedation are common causes, clinicians should not assume they alone account for patient hypotension and should consider other potentially dangerous causes, including pneumothorax and cardiac ischemia. Initial management of hypotensive episodes consists of boluses of IV crystalloid and careful monitoring of airway pressures. Critically ill patients may be depleted of endogenous catecholamines, causing hypotension, and may require treatment with exogenous catecholamines.

Mechanical ventilation is initiated. Ventilator settings may need modification according to clinical circumstance.

If long-term paralysis is needed, the timing of subsequent doses of both paralytic and sedative agents should be anticipated. Providing both long-term analgesia and sedation is important given the relatively short duration of action of some of the agents frequently used for RSI and the ability of paralysis to obscure the patient's capacity to communicate pain or distress. Appropriate sedation, guided by a sedation scale, often obviates the need for neuromuscular paralysis to permit mechanical ventilation.

**VARIATIONS OF TECHNIQUE** — The general approach described above is a commonly accepted way of performing rapid sequence intubation (RSI). There are, however, a number of variations, depending on clinical circumstance.

Accelerated sequence — The accelerated approach is useful for a critically unstable patient when there is not sufficient time for the full period of preoxygenation. In this case, the time line can be abbreviated by providing eight vital capacity breaths, rather than three to five minutes of tidal volume breathing. The pretreatment phase can also be accelerated to begin just prior to induction. If the patient is in extremis, the pretreatment phase can be eliminated altogether.
Timing principle — This concept has been described in the anesthesia literature and involves the administration of a relatively slower-onset paralytic agent prior to induction. The clinician waits for the early signs of the onset of paralysis before giving the induction agent. The purpose is to coordinate the onset of the paralytic and induction agents. It is possible the patient will experience a period of muscular weakness or paralysis while still awake if this approach is used. For this reason, the technique is not recommended or used in emergency medicine practice.

The timing principle should not be confused with the practice of administering a long-acting agent with a slower onset (eg, rocuronium) immediately prior to the induction agent, when both are given in rapid succession. This is done to coordinate the onset of action. The intention is to capitalize on the more rapid onset of the induction agent by giving it after the neuromuscular blocking agent (NMBA), affording the latter a bit more time to take effect.

Typically, when performing RSI using succinylcholine, the induction agent is given before the NMBA. The fundamental distinction between the timing principle and this approach is that the clinician does not wait for the onset of paralysis before giving the induction agent, but is merely reversing the order of the induction and paralytic agents to allow for their different times to effect.

SUMMARY AND RECOMMENDATIONS — Rapid sequence intubation (RSI) has become the mainstay of emergency airway management. RSI uses virtually simultaneous intravenous administration of a rapidly acting sedative (ie, induction) agent, in addition to a neuromuscular blocking (ie, paralytic) agent, to create optimal intubating conditions and enable rapid control of the airway. RSI presupposes the patient is at risk for aspiration of stomach contents and incorporates medications and techniques to minimize this risk. Use of RSI also helps to mitigate the potential adverse effects of airway manipulation. The basic approach to RSI consists of the "Seven P's":

- Preparation - Assess the patient for anatomic features or clinical findings that indicate the patient may be difficult to intubate or to ventilate using a bag-mask. Make an airway management plan, including a backup approach, based on the clinical scenario. Gather equipment and medications. Necessary equipment is described in the text.

- Preoxygenation - We recommend that any patient who may require endotracheal intubation be given high flow oxygen immediately (Grade 1B). Preoxygenation displaces nitrogen with oxygen, creating an oxygen reservoir in the lungs, blood, and tissues. This reservoir enables patients to tolerate a longer period of apnea without oxygen desaturation. The oxygen saturation of adults with severe illness or obesity, and pregnant women nearing the end of their third trimester, falls below 90 percent in less than three minutes, even if ideal preoxygenation is achieved. Time to desaturation in emergency practice is often more rapid than anticipated.

- Pretreatment - Depending upon clinical circumstance, specific medications may be given prior to the induction phase of rapid sequence intubation (RSI) for the purpose of mitigating adverse effects associated with intubation.

- Paralysis with induction - Rapid sequence intubation (RSI) involves the virtually simultaneous intravenous administration of a rapidly acting induction agent and a neuromuscular blocking agent (paralytic) aimed at producing a state of deep sedation and muscular relaxation quickly. Different induction agents are used depending on clinical circumstances.
• Protection and positioning - Refers to protecting the airway prior to placement of the endotracheal tube by avoiding bag-mask ventilation. Bag-mask ventilation is unnecessary if the patient has been successfully preoxygenated. Ventilation interposed between paralysis and intubation creates a potential risk for regurgitation and aspiration.

• Placement with proof - Once the intubation is performed, confirmation of proper endotracheal tube placement is crucial; unrecognized esophageal intubation leads to devastating complications. We recommend that an end-tidal CO2 determination (either colorimetric or quantitative) be performed to determine proper placement (Grade IB). In cardiac arrest patients not producing CO2, alternative means of confirmation, such as syringe or bulb devices, may be needed if CO2 is not detected. A single-view chest x-ray is only useful to determine depth of placement (eg, tracheal versus right mainstem). It is not useful for distinguishing endotracheal from esophageal intubation.

• Postintubation management - The endotracheal tube must be secured, a post-intubation chest x-ray checked for evidence of complications, and appropriate ventilator management started. Drugs used for RSI are generally short acting, and the clinician must provide adequate longer-term sedation, analgesia, and sometimes paralysis.

<table>
<thead>
<tr>
<th>Action</th>
<th>Time</th>
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<tbody>
<tr>
<td>Preparation</td>
<td>10 minutes before intubation</td>
</tr>
<tr>
<td>Preoxygenation</td>
<td>5 minutes before intubation</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>3 minutes before intubation</td>
</tr>
<tr>
<td>Paralysis with induction</td>
<td>Induction</td>
</tr>
<tr>
<td>Protection</td>
<td>30 seconds after induction</td>
</tr>
<tr>
<td>Placement</td>
<td>45 seconds after induction</td>
</tr>
<tr>
<td>Post-intubation management</td>
<td>60 seconds after induction</td>
</tr>
</tbody>
</table>
# Rapid sequence intubation induction agents

<table>
<thead>
<tr>
<th>Drug name</th>
<th>Class</th>
<th>Benefits</th>
<th>Contraindications</th>
<th>Notes</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etomidate</td>
<td>Imidazole derivative</td>
<td>Excellent sedation with little hypotension</td>
<td>None</td>
<td>Inform subsequent caregivers</td>
<td>0.3 mg/kg</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Known to suppress adrenal cortisol production</td>
<td>etomidate used</td>
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<td></td>
<td></td>
<td></td>
<td>Give initial dose of corticosteroid if patient has sepsis</td>
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<tr>
<td>Ketamine</td>
<td>Phencyclidine derivative, dissociative anesthetic</td>
<td>Stimulates catecholamine release</td>
<td>Controversial</td>
<td>May be an excellent induction agent for patients with elevated ICP AND hemodynamic compromise</td>
<td>1 to 2 mg/kg</td>
</tr>
<tr>
<td>Midazolam</td>
<td>Benzodiazepines</td>
<td>Potent dose-related amnesic properties</td>
<td>Dose-related myocardial depression can result in hypotension</td>
<td>Frequently underdosed</td>
<td>0.2 to 0.3 mg/kg</td>
</tr>
<tr>
<td>Propofol</td>
<td>Alkylphenol derivative</td>
<td>Bronchodilation</td>
<td>No absolute contraindications</td>
<td></td>
<td>1.5 to 3 mg/kg</td>
</tr>
<tr>
<td>Thiopental sodium</td>
<td>Ultrashort-acting barbiturate</td>
<td>Cerebroprotective and anti-convulsive properties</td>
<td>Acute intermittent and variegate porphyrias.</td>
<td></td>
<td>3 to 5 mg/kg</td>
</tr>
<tr>
<td>Methohexital</td>
<td>Barbiturate</td>
<td>Cerebroprotective</td>
<td>Acute intermittent and variegate porphyrias.</td>
<td>Rarely used</td>
<td>1 to 3 mg/kg</td>
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<tr>
<td></td>
<td></td>
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<td>Relatively contraindicated in reactive airway disease due to histamine release.</td>
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<td></td>
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<td></td>
<td>Potent venodilator and myocardial depressant: can cause hypotension.</td>
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