Outpatient Anesthesia

11

Robert Reti, David V. Valauri,
Michael H. Schiffman, Andre H. Montazem,
and Jason E. Portnoff

It should be no surprise that it is expected that you will perform safe outpatient anesthesia in your office. Per the AAOMS parameters of care, all patients whom are an ASA class II and above should be considered for consultation with a physician for medical clarification of the patient's medical condition and clearance to assist in making appropriate decisions for the setting and depth of anesthesia.

Accepted Definitions of Sedation and Anesthesia (AAOMS Parameters of Care 2017) [1] (Table 11.1)

Minimal Sedation (Anxiolysis) is a drug-induced state during which patients respond normally to verbal commands. Although cognitive function and physical coordination may be impaired, airway reflexes and ventilatory and cardiovascular functions are unaffected.

Moderate Sedation/Analgesia (Conscious Sedation) is a drug-induced depression of consciousness during which patients respond purposefully[1] to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.

Deep Sedation/Analgesia is a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully[1] following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.

General Anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to maintain ventilation function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-

[1]Reflex withdrawal from a painful stimulus is NOT considered a purposeful response.

R. Reti (✉)
Southwest Oral Surgery, St. Louis, MO, USA

D. V. Valauri
The Mount Sinai Hospital, Icahn School of Medicine, Oral & Maxillofacial Surgery/Otalaryngology, New York, NY, USA

M. H. Schiffman
Schiffman Oral Surgery, Woodmere, NY, USA

A. H. Montazem
Elmhurst Hospital Center, Oral/Maxillofacial Surgery, Elmhurst, NY, USA

J. E. Portnoff
Nova Southeastern University College of Dental Medicine, Department of Oral and Maxillofacial Surgery, Boca Raton, FL, USA

R. Reti, D. Findlay (eds.), *Oral Board Review for Oral and Maxillofacial Surgery*,
https://doi.org/10.1007/978-3-030-48880-2_11

Table 11.1 Continuum of depth of sedation: definition of general anesthesia and levels of sedation/analgesia

	Minimal sedation (anxiolysis)	Moderate sedation/ analgesia (conscious sedation)	Deep sedation/analgesia	General anesthesia
Responsiveness	Normal response to verbal stimulation	Purposeful response to verbal or tactile stimulation	Purposeful response after repeated or painful stimulation	Unarousable, even with painful stimulus
Airway	Unaffected	No intervention required	Intervention may be required	Intervention often required
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

Modified from Gross et al. [2]

induced depression of neuromuscular function. Cardiovascular function may be impaired. Because sedation is a continuum, it is not always possible to predict how an individual patient will respond. Hence, practitioners intending to produce a given level of sedation should be able to rescue[2] patients whose level of sedation becomes deeper than initially intended. Individuals administering moderate sedation/ analgesia should be able to rescue[2] patients who enter a state of deep sedation/analgesia, whereas those administering deep sedation/analgesia should be able to rescue[2] patients who enter a state of general anesthesia.

Airway Assessment

The goal of the evaluation is to predict the difficulty of mask ventilation and endotracheal intubation, should either be required during surgery. Critical components of the airway assessment include the patient's general appearance, dental exam, Mallampati score, maximum incisal opening, thyromental distance, mandibular protrusion, and BMI.

- *Dental Exam* – look for mobile/carious teeth, edentulism, crowns, dentures, orthodontic appliances, and large tongue/tonsils.
- *Mallampati Score* (See Fig. 11.1) – Original classification scheme was first described in 1985 as a clinical sign to predict difficult intubation and included 3 classes. In the modified Mallampati (by Samsoon and Young) a 4th class is included. Score of 3 or 4 indicates potential difficult intubation. Assessment of patient seated upright with head in neutral position, mouth open, tongue protruded without phonation.
  - Class I: soft palate, uvula, tonsillar pillars, and fauces are visible.
  - Class II: superior 2/3 of uvula and soft palate are visible.
  - Class III: <1/3rd of uvula and soft palate are visible.
  - Class IV: soft palate not visible.
- *Maximum Incisal Opening* (MIO) – normal is >40 mm, <35 mm should be considered limited. Be cautious of patients with a history of temporomandibular joint disorders or a history of head and neck radiation. The ability to perform specific airway maneuvers depends in part on the degree that a patient is able to maximally open. At a MIO of 20 mm, it is possible to insert an oral or nasal airway, GlideScope ™, and perform a fiberoptic intubation. As the MIO increases to 30 mm, insertion of a laryngeal mask airway (LMA) becomes possible. At a MIO of 40 mm, direct laryngoscopy (DL) intubation may be performed.

[2]Rescue of a patient from a deeper level of sedation than intended is an intervention by a practitioner proficient in airway management and advanced life support. The qualified practitioner corrects adverse physiologic consequences of the deeper-than-intended level of sedation (such as hypoventilation, hypoxia, and hypotension) and returns the patient to the originally intended level of sedation.

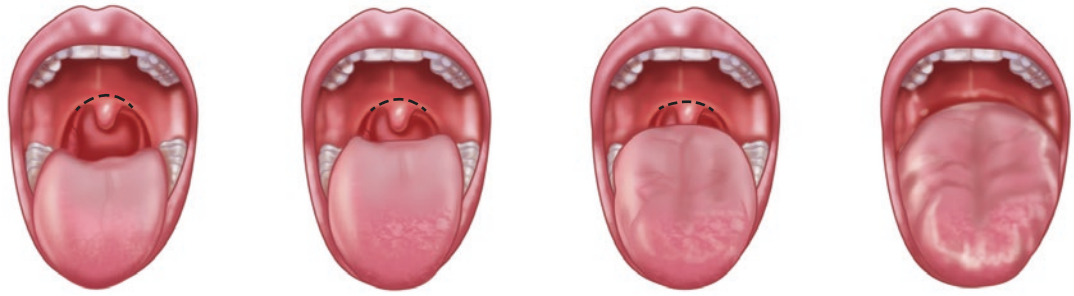

Fig. 11.1 Mallampati classification. (Reprinted with permission from Strauss and Noordhoek [11])

- *Thyromental Distance* – the distance between the top of the thyroid cartilage and the menton of the mandible. It is an indicator of the ability to displace the tongue during direct laryngoscopy. A distance of <6.5 cm (three finger breadths) may indicate difficulty with intubation.
- *Mandibular Protrusion* – evaluate patient's ability to protrude the lower jaw so that the mandibular incisors are in front of the maxillary incisors. This maneuver correlates with the clinician's ability to sublux the mandible during laryngoscopy.
- *Upper Lip Bite Test* (ULBT) – assesses a patient's ability to reach and cover their upper lip with their mandibular incisors (similar to mandibular protrusion test).
  - Grade 1: fully covers the upper lip with lower incisors.
  - Grade 2: partially covers the upper lip with lower incisors.
  - Grade 3: cannot reach the upper lip with lower incisors.
- *Body Mass Index (BMI) and Obesity* – patients often have increased parapharyngeal fat which can cause difficulty with airway maneuvers and these patients are more prone to desaturation during sedation. On the opposite spectrum, be extremely cautious of those with a BMI of <18.5, as they are at a higher rate of mortality with anesthetic challenges. Patients with a BMI of <18.5 are more prone to hypokalemia, dehydration, delayed gastric emptying, decreased GFR, and have a predisposition to aspiration.
  - BMI Scale (m/kg^2):
    Normal: 18.5–24.9
    Overweight: 25–29.9
    Obese: 30–39.9
    Morbidly obese: 40–49.9
    Super obese: >50
- *Neck Circumference* – if greater than 43 cm (17 inches), associated with difficulty for intubation, more predictive than BMI.

Laboratory Tests and Other Studies

- Testing should be based on the history and physical of the patient and the nature of the surgical procedure.
- An electrocardiogram (EKG) should be obtained in all adults over the age of 65, and any patient with a history of hypertension (HTN), cardiac disease, substance abuse, or eating disorder.
- A fasting fingerstick glucose (FSG) should be obtained on all diabetics both prior to surgery and postoperatively prior to discharge.
- Other lab tests that may be indicated depending on the patient's reported history include Hematocrit (Hct), chest X-ray (CXR), urine pregnancy test (b-hCG), BMP, LFTs, coagulation studies, or echocardiogram.

Evaluation of Functional Status

- During the preoperative evaluation, it is important to ask patients about their exercise

capacity, as this is a significant determinant of perioperative risk. In general, patients with good exercise tolerance are at lower risk for cardiopulmonary complications during anesthesia. One commonly used measure of exercise tolerance is metabolic equivalent tasks (METs).

- MET is a physiological measure that expresses the energy cost of performing various physical activities. It is expressed as the ratio of a patient's metabolic rate during a specific physical activity over the reference metabolic rate, which is the resting or basal oxygen consumption of a 40-year-old, 70-kg man (3.5 mL O_2/kg/min or MET 1) [3].
- Perioperative risk is elevated in patients with <4 METs. Activities of <4 METs include watching TV, shopping, golfing with a cart, and walking slowly (2–3 mph).
- Activities associated with >4 METs include climbing a flight of stairs, bicycling, walking >4 mph, and performing housework.

American Society of Anesthesiology (ASA) Classification

American Society of Anesthesiology Clinical Information [Internet]. Schaumburg, IL: American Society of Anesthesiologists; 2017. ASA physical status classification system; [approved 2014 Oct 15; Available from: https://www.ncbi.nlm.nih.gov/books/NBK441940/]

- ASA Class I: A healthy patient (healthy, nonsmoking, no or minimal alcohol use).
- ASA Class II: *mild* systemic disease (WITHOUT substantive functional limitations).
  - For example, current smoker, social alcohol drinker, pregnancy, obesity (BMI 30–40), well-controlled DM/HTN, mild lung disease.
- ASA Class III: *severe* systemic disease that *limits activity but is not incapacitating* (substantial functional limitations).
  - For example, poorly controlled DM/HTN, COPD, morbid obesity (BMI ≥40), active hepatitis, alcohol dependence or abuse, implanted pacemaker, moderate reduction of ejection fraction, ESRD undergoing regularly scheduled dialysis, history (>3 months) of MI, CVA, TIA, or CAD/stents.
- ASA Class IV: *severe* systemic disease that is a *constant threat to life*.
  - For example, recent (< 3 months) MI, CVA, TIA, or CAD/stents, ongoing cardiac ischemia or severe valve dysfunction, severe reduction of ejection fraction, sepsis, DIC, ARD, or ESRD not undergoing regularly scheduled dialysis.
- ASA Class V: moribund patient who is not expected to survive without operation.
- ASA Class VI: declared brain-dead patient whose organs are being removed for donor purposes.
- The addition of "E" denotes emergency surgery – added when a delay in treatment of the patient would lead to a significant increase in the threat to life or body part.

NPO Guidelines

In 2017, the American Society of Anesthesiology published a set of practice guidelines regarding preoperative fasting prior to anesthesia. These guidelines were meant to reduce the occurrence and severity of complications related to perioperative pulmonary aspiration of gastric contents [4].

The ASA's preoperative fasting guidelines for elective procedures requiring general anesthesia, regional anesthesia, or sedation/analgesia are summarized as follows:

- Clear liquids – at least 2 hours.
  - Examples of clear liquids include water, fruit juice without pulp, carbonated beverages, clear tea, plain gelatin, and black coffee. These liquids should *NOT* include alcohol. The volume of liquid ingested is less important than the type of liquid ingested.
- Breast milk – at least 4 hours.
- Infant formula – at least 6 hours.

- Non-human milk – at least 6 hours.
- Solids, light meals, non-clear liquids – at least 6 hours.
- Heavy meal or fried/fatty foods – at least 8 hours.

Note: The routine use of preoperative gastrointestinal stimulants (e.g., metoclopramide), medications that block gastric acid secretion (e.g., H_2 antagonists, PPIs), antacids (e.g., sodium citrate, magnesium trisilicate), antiemetics (e.g., droperidol, ondansetron), to decrease the risk of pulmonary aspiration in patients who have no apparent increased risk for pulmonary aspiration is *NOT* recommended. The use of anticholinergics (e.g., atropine, glycopyrrolate) is *NOT* recommended to reduce risk of pulmonary aspiration.

Airway Management

Oxygen Delivery Methods

Mouth to Mouth

- Exhaled air contains 17% oxygen.

Nasal Cannula

- Each increase liter per minute is approximately 4% above room air.
- $FiO_2 = 20 + [4 \text{ L/min} \times \text{L/min}]$.
- Flow greater than 4 L/min, although delivering 36%, may be uncomfortable.

Simple Facemask

- Flow 8–12 L/min.
- FiO_2: 35–65%.
- Increase approximately 4% per liter flow.

Non-Rebreather

- Flow rate should be min 6–15 L/min.
- FiO_2: 60–100%.
- Delivered oxygen ~60%, each L/min increase will raise FiO_2 ~5%.

Mask Ventilation

- Can be used for spontaneously breathing patients or apneic patients via positive pressure ventilation.
- Uses:
  - Primary means of ventilation for a short procedure.
  - Bridge to establishing a more definitive airway.
  - Pre-oxygenation prior to GA induction.
  - Valuable rescue technique when intubation proves difficult.
- Caution if full stomach, severe facial trauma or C-spine fracture.
- Difficulty occurs when ventilating via the facemask is not possible because of an inadequate mask seal (e.g., beard hair), excessive gas leak, and/or excessive resistance to the ingress or egress of gas. This may be helped by oro/naso-pharyngeal airways.
- Risk factors for bag mask ventilation difficulty include age greater than 55 years, BMI > 26 kg/m^2, edentulism, presence of a beard, and history of snoring [5].

Oropharyngeal Airways

- Follows the curvature of the tongue, pulling the tongue and epiglottis away from the posterior pharyngeal wall.
- Not appropriate for use in conscious patients (can cause coughing, retching, or laryngospasm due to irritation at base of tongue). Best used in the deeply anesthetized patient.
- Sized by measuring from the corner of a patient's mouth to the angle of the jaw.

Nasopharyngeal Airways

- Less stimulating than oropharyngeal airways, more appropriate for lightly anesthetized patients.
- Lubricate prior to insertion and insert with the bevel facing the nasal septum.

Laryngeal Mask Airway (LMA)

- Supraglottic airway that is blindly inserted into the pharynx.
- Provides a patent conduit for ventilation, oxygenation, and delivery of anesthetic gases without tracheal intubation.
- Less invasive than intubation but provides a more definitive airway than a facemask.
- Can be used for either spontaneous ventilation or PPV.
- Allows for delivery of O_2 and inhaled anesthetics during spontaneous ventilation or via PPV at pressures up to 20 cmH_2O.
- Flexible LMA Tube – allows the tube to be moved out of the surgical field without displacement of the cuff, or loss of seal for the anesthesiologist.

Endotracheal Intubation

- Gold standard for airway management.
- Establishes a definitive airway.
- Maximal protection against aspiration of gastric contents.
- Allows for delivery of O_2, inhalational anesthetics and allows for PPV with higher airway pressures than with a facemask or supraglottic airway (LMA).

Emergency Percutaneous Airways

Cricothyrotomy

- Invasive technique that provides access to the airway in situations when either noninvasive maneuvers have failed or when it is clinically indicated as a primary plan to secure the airway.
- Not considered a permanent airway, and after placement plans should be made for either the removal or conversion to a formal tracheostomy.
- Technique:
  - Step 1: Extend the head and neck and identify and immobilize the cricothyroid membrane. (Make an initial vertical incision if identification is not possible.)
  - Step 2: Make a horizontal stab incision through the skin and cricothyroid membrane and keep the blade in place.
  - Step 3: Use a tracheal hook to apply caudal and outward traction on the cricoid cartilage; remove the scalpel.
  - Step 4: Insert the ETT tube (6.0 cuffed mm) or tracheostomy tube (No.4 cuffed tracheostomy tube) and inflate the cuff.
  - Step 5: Ventilate with a low-pressure source.
  - Step 6: Confirm pulmonary ventilation.
- Note: In children <6 years of age, cricothyrotomy is contraindicated because the cricoid cartilage is the narrowest portion of the airway and the isthmus of the thyroid gland typically reaches the level of the cricothyroid membrane. Needle cricothyrotomy with transtracheal jet ventilation is indicated in this pediatric population.
- Conversion to tracheostomy is normally recommended within 72 hours to prevent subglottic stenosis [6].

Transtracheal Needle Ventilation

- Allows for 30 minutes to 2 hours of ventilation.
- Must be avoided in those with tracheal trauma.
- Technique:
  - Step 1: Extend the head and neck and identify and immobilize the cricothyroid membrane. Normally it is 2 cm in width and 2–3 cm below the laryngeal prominence [7].
  - Step 2: Puncture cricothyroid membrane at a 90° angle with saline-filled syringe with 14 gauge catheter needle for adults or 18 gauge for pediatric and draw back until air enters the syringe. This indicates entry to airway.
  - Step 3: Advance catheter off caudally at a 30–45° angle.
  - Step 4: Attach syringe to 100% wall oxygen at 50 psi for adults, 10–25 psi for children 8 years or older, or 5–10 psi for children 5–8 years of age [7]. A bag-valve mask using the connector from a 7 ET tube inserted into the back of a plunger less 3 mL Luer-lock syringe can also be used.

Pediatric Airway and Anatomy Considerations

Pediatric Airway Is Smaller

- In the pediatric airway, there is greater risk of airway obstruction from small foreign bodies.
- Minimal swelling of the small pediatric airway will result in a relatively greater reduction in airway diameter than would occur in the larger airways of the adult.
- The internal diameter of the appropriate endotracheal tube for a child will roughly equal the size of that child's little finger, but this estimation may be difficult and unreliable.
- For children 1–10 years of age, an estimate based on the child's age is available using the following equation.
- Uncuffed endotracheal tube size = (age in years/4) + 4.
- Intubation is preferred method of airway security.
- Cricothyroidotomy is contraindicated in children less than 12 years of age.
- Emergent airway is a tracheostomy.

Large Tongue Relative to a Small Mouth

- This increases the risk of the tongue obstructing the airway than in the adult. This makes it essential that there is correct positioning of the head and jaw when opening the airway.

Infants Have a Larger Occiput

- The large occiput of the infant flexes the head forward when he/she is placed prone on a flat surface. This is important in airway-opening maneuvers and cervical spine immobilization.
- Care must be taken not to hyper-extend the neck, as this may result in airway obstruction or spinal cord damage in the event of a cervical spine fracture.

Infants Are Obligatory Nose Breathers

- In the first 4–6 months of age, infants breathe exclusively through the nose and will experience respiratory distress if the nose is blocked. Care must be taken to ensure that the nares are patent in cases of trauma involving the infant patient.

Trachea/Presence of Tonsils and Adenoids

- The cartilaginous nature of the pediatric airway renders it soft which makes it more collapsible than the adult airway.
- The tonsils in toddlers and young children may be enlarged, contributing to airway obstruction and making nasal passage of an endotracheal tube difficult.

Larynx Is Higher and More Anterior

- The larynx sits at the level of the 2nd–3rd cervical vertebrae in the young child, compared with the 6th–7th cervical vertebrae in the adult.

Shape of the Epiglottis

- The epiglottis of the young child is floppy and projects posteriorly. This makes the technique of tracheal intubation more difficult.

Cricoid Ring Is the Narrowest Point in the Airway

- The cuff of the endotracheal tube sits at the level of the cricoid ring, which then takes up valuable airway diameter. In addition, the cricoid region is lined with pseudostratified, ciliated epithelium bound to areolar tissue, which is susceptible to edema. For these reasons, an uncuffed endotracheal tube is used for pediatric intubation.

The Length of the Trachea Is Smaller

- The pediatric trachea is comparatively shorter than that of the adult, and the risk of dislodgement of the endotracheal tube is greater.

Cervical Spine

- Larger head, in particular in the occipital region. This has been previously discussed with regard to the airway. However, it is also very important in cervical spine alignment. The ligaments of the pediatric vertebral column are relatively lax, compared to those in the adult spinal column. This increases the likelihood that movement of vertebrae may occur, resulting in injury to the normal spinal cord.
- The fulcrum is at C1–2 not C6–7. Therefore, cervical spine injuries in children under the

age of 8 most commonly occur in the first three vertebrae, whereas in the adult, injuries tend to be lower in the vertebral column.

Difficult Airway Algorithm [8]

The figure below (see Fig. 11.2) summarizes the steps for the management of the difficult airway.

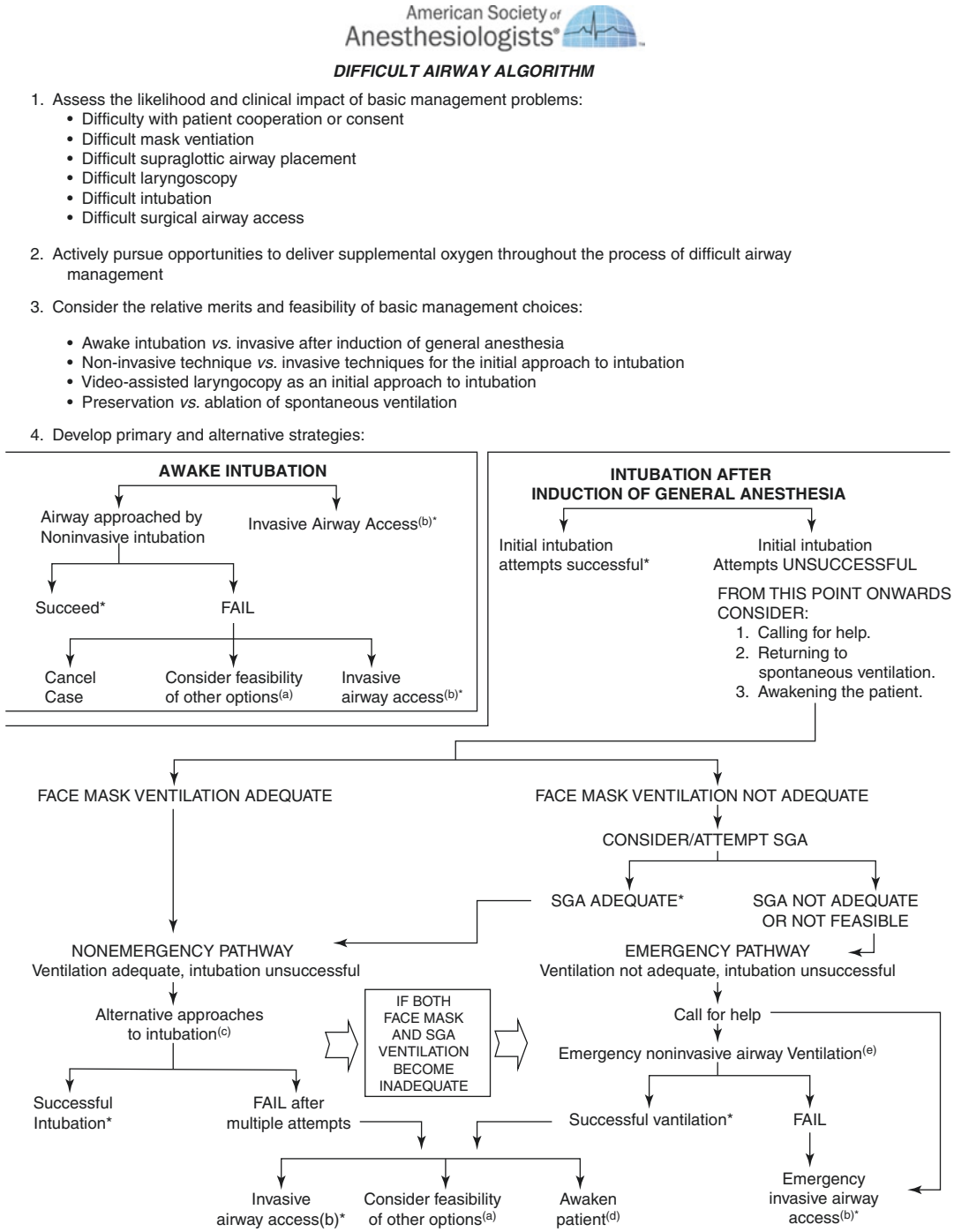

Fig. 11.2 Difficult airway management algorithm. (Reprinted with permission from Apfelbaum et al. [8])

AAOMS Standards for Basic Anesthetic Monitoring During Deep Sedation and General Anesthesia [1]

- During all anesthetics, the patient's oxygenation, ventilation, circulation should be continually evaluated.
- Temperature measurement instruments should be available.

Oxygenation

- Must use a quantitative method of assessment such as pulse oximetry – the variable pitch pulse tone and low threshold alarm must be audible to the anesthesia provider.
- *Pulse Oximetry*
  - Based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin.
  - Photodetector only amplifies light of an alternating intensity (pulsating artery).
  - Oxygenated Hgb absorbs more infrared light and allows more red light to pass through.
  - Deoxygenated (reduced) Hgb absorbs more red light and allows more infrared light to pass through.
  - Two wavelengths emitted: (1) 660 nm (deoxygenated Hgb) and (2) 940 nm (oxygenated Hgb).
  - After the transmitted red and infrared signals pass through the measuring site and are received at the photodetector, the oxygenated vs. non-oxygenated Hgb to the total amount of Hgb is expressed as a fraction of the hemoglobin pool in the oxygenated form.
  - False high readings occur with carbon monoxide as COHgb (elevated in smokers).
  - Methemoglobinemia will overestimate the SaO_2, and readings will not fall below 85%.
  - SpO_2 reported as accurate with a systolic BP > 80 mmHg.
  - Oximetry is in the presence of anemia accurate to 2–3 g/dL of hemoglobin.

Ventilation

- Continual monitoring for the presence of expired carbon dioxide (end tidal CO_2 Fig. 11.3).
- Continual observation of chest rise and auscultation of breath sounds (consider precordial stethoscope).

Circulation

- The electrocardiogram (ECG) shall be continuously displayed from the beginning of anesthesia until preparing to leave the anesthetizing location. Leads II and V5 are more sensitive to ischemia.
- Arterial blood pressure and heart rate must be determined and evaluated at least every 5 minutes.
- If providing general anesthesia, must continually evaluate circulatory function by at least one of the following: palpation of a pulse, auscultation of heart sounds, monitoring of a tracing of intra-arterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry.

Temperature

- Must be monitored when clinically significant changes in body temperature are intended, anticipated, or suspected.

Recovery and Discharge Assessment

Modified Aldrete Score

Assigns a score of 0–2 to the following categories: activity, breathing, circulation, consciousness, and oxygen saturation (Table 11.2) [10].

A score of 9 out of 10 is required for discharge from the facility/PACU.

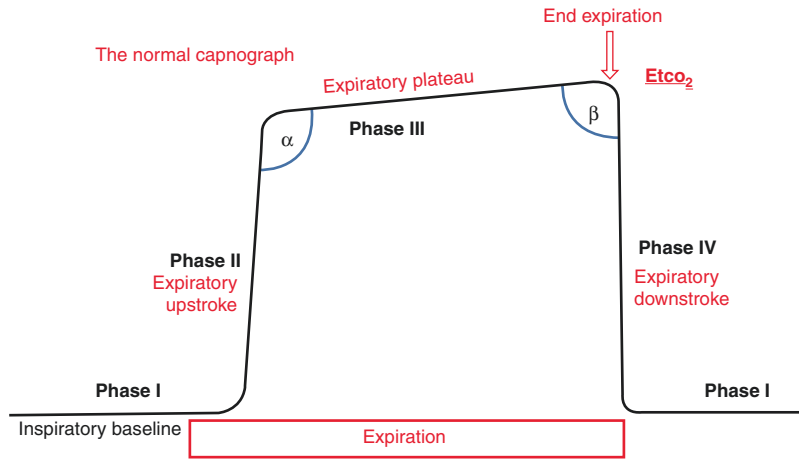

Fig. 11.3 The capnographic of the normal waveform. Evaluated with the change in concentration of CO_2 (mmHg) gas over a function of time (normally seconds). Phase 1 – exhalation of CO_2 free gas from dead space (inspiratory baseline). Phase 2 – rapid rise in CO_2; combination of dead space and alveolar gas. Slow uptake in this phase may represent an upper airway obstruction, obstruction of the endotracheal tube, or bronchospasm. A shark fin pattern, without an expiratory plateau, may be suggestive of obstructive lung disease such as asthma of COPD. Phase 3 – exhalation of mostly alveolar gas (expiratory/alveolar plateau). Phase 4 – inhalation with return to baseline CO_2 concentration levels (expiratory downstroke). (Reprinted with permission from Manifold et al. [9])

Table 11.2 Modified Aldrete score

Variable evaluated	Score
Activity	
Able to move 4 extremities on command	2
Able to move 2 extremities on command	1
Able to move NO extremities on command	0
Breathing	
Able to breathe deeply and cough freely	2
Dyspnea	1
Apnea	0
Circulation	
Systemic blood pressure ≤20% of preanesthetic level	2
Systemic blood pressure 20–30% of preanesthetic level	1
Systemic blood pressure ≥50% of preanesthetic level	0
Consciousness	
Fully awake	2
Arousable	1
Not responsive	0
Oxygen saturation (pulse oximetry)	
>92% while breathing room air	2
Needs supplemental O_2 to maintain saturation >90%	1
<90% with supplemental O_2	0

Pharmacological Principles

Pharmacokinetics

- Describes the absorption, distribution, metabolism, and excretion of drugs.
- Describes how the body affects the drug.

Pharmacodynamics

- Describes therapeutic and toxic organ system effects of drugs.
- Describes how the drug affects the body.
- Knowledge of a drug's pharmacokinetics and pharmacodynamics defines the relationship between the dose of drug administered and the resulting pharmacological effect as depicted by the dose-response curve.

Theories of Anesthetic Action

Past understanding of anesthetic actions attempted to identify a unitary hypothesis of

anesthetic effects. This hypothesis proposes that all inhalation agents share a common mechanism of action at the molecular level. This was previously supported by the observation that the anesthetic potency of inhalation agents correlates directly with their lipid solubility (Meyer-Overton rule). There is an ongoing debate as to the mechanism of anesthetic action. Anesthetic interactions at specific protein ion channels, as well as more nonspecific membrane effects, may combine to produce the anesthetized state.

General anesthesia is an altered physiological state characterized by reversible loss of consciousness, analgesia, amnesia, and some degree of muscle relaxation. The multitude of substances capable of producing general anesthesia is remarkable: inert elements (xenon), simple inorganic compounds (nitrous oxide), halogenated hydrocarbons (halothane), ethers (isoflurane, sevoflurane, desflurane – see Table 11.3), and complex organic structures (propofol). A unifying theory explaining anesthetic action would have to accommodate this diversity of structure. In fact, the various agents probably produce anesthesia by differing sets of molecular mechanisms. Inhalational agents interact with numerous ion channels present in the CNS and peripheral nervous system. Nitrous oxide and xenon are believed to inhibit N-methyl-D-aspartate (NMDA) receptors. NMDA receptors are excitatory receptors in the brain. Other inhalational agents may interact at other receptors (e.g., gamma-aminobutyric acid [GABA]-activated chloride channel conductance) leading to anesthetic effects.

Table 11.3 Different MAC values for commonly used inhalation anesthetics

MAC in adults 30–55 years		
Anesthetic	In O_2	In 60–70% N_2O
Desflurane	6.00	2.83
Halothane	0.75	0.29
Isoflurane	1.15	0.50
Sevoflurane	2.3	1.3
Xenon	71	
Nitrous oxide	104	—

MAC (Minimal Alveolar Concentration)

- Minimum alveolar concentration or partial pressure at one ATM which will prevent "gross purposeful movement" in response to a surgical stimulus in 50% of patients (essentially ED_{50}).
- Clinically, 1.25–1.3 times MAC is required to include 90+% of patients.
- Higher MAC, the less potency of the inhalational anesthetic (Table 11.3).
- Choice of inhalation agent is commonly determined by its physiological effects on the body (Table 11.4).

This Level of Partial Pressure Gradient Depends Upon

- F_i Inspired concentration.
- V_m Minute volume.
- Transfer to the alveoli.
- Transfer from the alveoli.
- CO Cardiac output.
- AV Partial pressure gradients.
- Transfer to the brain.

Other Factors that Influence the Uptake or Elimination of Inhalational Agents

- Concentration Effect – when an inhalational agent is administered in a low concentration, for example 1% volume, uptake of half the volume results in a 0.5% volume concentration. If, however, 80% volume concentration is administered, uptake of half the volume

Table 11.4 Cardiovascular effects of inhalational anesthetics compared

	Cardiac output	Systemic vascular resistance	Mean arterial pressure	Heart rate
Halothane	↓	↔	↓	↓↓
Enflurane	↓↓	↓	↓↓	↑
Isoflurane	↓	↓	↓	↑
Desflurane	↔	↓	↓	↑
Sevoflurane	↔	↓	↓	↔
N_2O	↓	↑	↔	↑
Xenon	↔	↔	↔	↓

results in a 66–70% volume concentration as the alveolar volume contracts.
- Second Gas Effect – when two inhalational agents are administered (one in a large concentration and another in a small concentration), the first agent may increase the concentration of the second agent. This follows the same concept as the concentration effect.
- Diffusion Hypoxia – the rapid wash out of oxygen by an inhalational agent, which results in a hypoxic alveolar concentration of oxygen.
- Overpressure Technique – in order to rapidly establish the desired partial pressure of an inhalational agent, the circuit is primed at the highest concentration and the agent is delivered at high concentration via facemask until the rapid induction is achieved. This technique, in conjunction with pre-priming of the circuit with the maximum deliverable concentration of agent will allow "Vital Capacity Induction."

Wash Out or Elimination

In general, wash out is the inverse of wash in. Factors affecting wash out include agent solubility, duration of anesthetic, and minimally, metabolism.

Inhalation Considerations

1. Soda Lime Reactions:

- Carbon dioxide absorption is important to allow rebreathing of volatile agents possible. Usually NaOH or KOH mixed with hardeners such a silica and kieselguhr. Contain an indicator that changes color when exhausted.
- CO is produced from extremely dry soda lime.
- Sevoflurane is unstable in soda lime and produces a Compound A (Compound A is nephrotoxic).
- Amsorb is used instead of soda lime, which eliminates these reactions.

2. Halothane Hepatitis

- About 20% of halothane is metabolized to trifluoroacetic acid, chloride, and bromide.
- Trifluoroacetic acid combines with liver proteins forming a hapten that activates an antibody reaction on repeated exposure leading to immune-mediated liver destruction.

Intravenous Agents

Propofol (Diprivan®)

- Sedative-hypnotic.
- Propofol: 2,6-diisopropylphenol 1% injectable emulsion that is an intravenous sedative-hypnotic agent used for induction and maintenance of anesthesia or sedation.
- Mechanism of action is via potentiation of GABA receptor, causing depression of the reticular activating system.
- It contains soybean oil, glycerol, egg lecithin, and depending upon the manufacturer it may contain EDTA, sodium metabisulfite or benzyl alcohol to retard microbial growth.
- It has a fast onset of action, usually within 40 seconds (one arm-brain circulation) due to high lipid solubility.
- Short duration of action is due to rapid clearance. Propofol is primarily metabolized in the liver and then excreted by the kidneys. The metabolites of propofol are thought to be inactive.
- Extra-hepatic metabolism of propofol occurs in the kidneys. A minor amount of propofol is excreted unchanged in the feces and lungs.
- Propofol has a half-life of 4–7 hours and a clearance of 20–30 (mL/kg/min).
- Central Nervous System (CNS) Effects:
  - The hypnotic action of propofol is mostly mediated by binding to the GABA receptor sites.
  - Propofol has poor analgesic properties.
  - It reduces intracranial pressure (ICP) and cerebral blood flow (CBF).
  - It has anticonvulsant and antiemetic effects.
- Cardiovascular System Effects:
  - A cardiovascular depressant with direct myocardial depression (negative inotropism), decrease in systemic vascular resistance and hypotension. Inhibits normal

baroreflex response to hypotension with only a small increase in heart rate.
  - Bradycardia and asystole have occurred in healthy adults after propofol induction.
- Respiratory System Effects:
  - Profound respiratory depressant.
  - Causes apnea following induction dose.
  - Inhibits hypoxic respiratory drive and depresses normal response to hypercarbia.
  - Reduction in tidal volume and respiratory rate causing reduction in minute ventilation.
  - Reduction in upper airway reflexes and protects against bronchospasm via bronchodilation.
  - Lower incidence of wheezing on induction.
- Side Effects:
  - Pain on injection is common. This can be reduced by prior injection of lidocaine or mixing propofol with lidocaine.
  - Muscle twitching, spontaneous movement, or hiccupping can occur with propofol induction.
- Caution needed for the following patients:
  - Elderly – consider 20% lower doses, administer bolus more slowly and/or in smaller increments.
  - Impaired cardiac function – use lower doses or select other agents.
  - Reports of avoidance with patients with peanut, soy, and egg allergy. A review by the American Academy of Allergy, Asthma and Immunology reports its safe use in these patients without special precautions. The majority of reports on allergic reaction to propofol have involved patients without allergy to peanuts, soy, or egg.
- Clinical Uses:
  - *Induction of General Anesthesia*
    Adults: 1–2.5 mg/kg
    Children: 2.5–3.5 mg/kg
  - *Maintenance of GA*
    Infusion of 100–200 mcg/kg/min
  - *Sedation*
    Infusion of 25–100 mcg/kg/min
    Intermittent bolus (adults): 20–50 mg
  - *Antiemetic*
    10–20 mg bolus

Ketamine (Ketalar®)

- Partially water-soluble and highly lipid-soluble derivative of phencyclidine. It provides dissociative anesthesia, which causes disassociation between thalamus and limbic system. It also renders the patient in a cataleptic state where the patient appears conscious but is unable to process or respond to a stimulus.
- N-methyl-D-aspartate (NMDA) receptor antagonist.
- Potent analgesic.
- High lipid solubility and low protein binding ensure rapid onset of action.
- Metabolized in the liver to several metabolites, some of which retain activity (norketamine).
- Inactive metabolites excreted by the kidneys.
- Central Nervous System Effects:
  - Increases CBF and ICP.
  - Anticonvulsant effect.
  - Induces analgesia, amnesia, and hypnotic properties.
  - Unpleasant psychomimetic effects.
  - Not recommended for patients with intracranial pathology.
  - Emergence Phenomenon: vivid, disturbing dreams, hallucinations, out-of-body experience, and delirium. These reactions are limited by pretreatment with benzodiazepines.
- Cardiovascular System:
  - Significant increase in systemic blood pressure, heart rate, and cardiac output.
  - These indirect effects result from centrally mediated sympathetic stimulation.
- Respiratory System:
  - Ventilatory drive is minimally affected with induction dose.
  - Transient hypoventilation and rarely apnea can follow a rapid intravenous bolus.
  - Upper airway reflexes remain largely intact.
  - It is a potent bronchodilator.
- Side Effects:
  - Psychomimetic effects.
  - Increase in salivation; attenuated by premedication with an anticholinergic such as glycopyrrolate.

  - Can increase the risk of laryngospasm, especially in children.
- Clinical Uses:
  - *Premedication for special needs patients and uncooperative pediatric patients.*
  - *Induction of GA.*
    IV: 1–2 mg/kg.
    IM: 3–5 mg/kg.
  - *Sedation.*
    IV: 0.2–0.5 mg/kg, intermittent boluses.
    PO: 1mg/kg.

Midazolam (Versed®)

- 1,4-Benzodiazepine compound.
- Sedative-hypnotic.
- Mechanism of action is via GABA potentiation.
- Water soluble, converts to lipid-soluble compound by exposure to pH of blood.
- Administered IV, IM, IN.
- Intranasal, buccal, and sublingual administration of midazolam is effective.
- Highly lipid soluble ensures rapid onset.
- Highly protein bound.
- Metabolized by liver with metabolites mainly excreted in urine.
- Fast onset.
- Excellent anterograde amnesia.
- Central Nervous System Effects:
  - Activation of GABA receptor complex.
  - Minimal effect outside CNS.
  - Anterograde amnesia and anxiolysis.
  - Anticonvulsant.
  - Mild muscle relaxant mediated at spinal cord level.
  - Reduce CBF and ICP.
- Cardiovascular System Effects:
  - Minimal effects: Slight decrease in arterial blood pressure, cardiac output, and peripheral vascular resistance.
- Respiratory System Effects:
  - Minimal depression of ventilation.
  - Decreased ventilatory response to CO_2, which is usually not significant. It is more severe when administered in conjunction with opioids.
- Side Effects:
  - Allergic reactions extremely rare to nonexistent.
  - Hiccups (singultus) upon administration.
- Clinical Uses:
  - *Premedication and sedation.*
    IV: 1–2 mg/kg.
    PO: 0.5–1 mg/kg.
    IM: 0.05–0.1 mg/kg.
    IN: 0.5 mg/kg.
  - *Induction of GA.*
    IV: 0.1–0.4 mg/kg.
  - Suppression of seizure activity.
  - Sedative effects are increased with elderly patients, decreased doses are recommended.
- *Reversal by Flumazenil (Romazicon®)*
  - Flumazenil is a benzodiazepine receptor ligand with high affinity. It interacts with the receptor in a concentration-dependent manner. It is a competitive antagonist at the benzodiazepine receptor site. It does not displace the agonist, but rather occupies the receptor when an agonist dissociates from the receptor.
  - Initial dose: 0.2 mg IV one time over 15 seconds.
  - Repeated doses: 0.2 mg may be given every minute until the desired level of consciousness is achieved.
  - Maximum total dose 1 mg.
  - Most patients respond to 0.6–1 mg.

Fentanyl (Sublimaze®)

- Narcotic agonist-analgesics of opiate receptors (primarily μ) that inhibit ascending pain pathways.
- Fast onset and short duration of action.
- Primarily metabolized by the liver (CYP3A4).
- End products mostly eliminated by the kidneys.
- Central Nervous System Effects:
  - Analgesia and sedation without loss of consciousness.
  - Tolerance and dependence with repeated opioid administration.
  - Higher incidence of nausea vomiting due to stimulation of chemoreceptor trigger zone in the medulla oblongata.

- Cardiovascular System Effects:
  - In general, does not seriously impair cardiovascular function.
  - Causes bradycardia.
  - Arterial blood pressure often falls from bradycardia, vasodilation, and decreased sympathetic reflexes.
- Respiratory System Effects:
  - Depress ventilation, especially respiratory rate.
  - Apneic threshold is elevated and hypoxic drive is decreased.
  - Can induce chest wall and laryngeal muscle rigidity.
- Side Effects:
  - Nausea and vomiting due to stimulation of chemoreceptor trigger zone in the medulla.
  - Constipation.
  - Tolerance and physical dependence with repeated administration.
  - Pruritus.
  - Hypothermia.
  - Shivering.
- Clinical Use:
  - 2 μg/Kg IV.
  - *Opioid Reversal by Naloxone* (Narcan®).

    Naloxone is a competitive opioid receptor antagonist.

    Its affinity for opioid μ receptors appears to be much greater than for opioid κ or δ receptors. Naloxone has no significant agonist activity.

    Initial adult dose: 0.4 mg to 2 mg IV.

    If the desired response is not obtained, doses should be repeated at 2–3 minute intervals, generally up to a total dose of 10 mg.

    Initial pediatric dose: 0.01 mg/kg IV; if desired response is not obtained, may give 0.1 mg/kg IV.

Neuromuscular Blocker Agents

Succinylcholine (Anectine®)

- A depolarizing noncompetitive agent that works at the cholinergic receptor, which has a rapid onset (30–60 seconds) and short duration (2–3 minutes).
- It is associated with muscular pain and anaphylactic reactions.
- It is known as a trigger agent for malignant hyperthermia.
- Repeated doses are associated with bradycardia and possible asystole. Pretreatment with atropine lessens this complication.
- Rarely (1 in 4000 patients), a deficiency of the enzyme pseudocholinesterase occurs, which would prolong its metabolism and thus the duration of action substantially.
- *Clinical Use*:
  - Facilitation of endotracheal intubation and rescue from laryngospasm. Consider pretreatment with atropine.
  - Intubation dose: 0.3–1.1 mg/kg IV single bolus.
  - Rescue from laryngospasm dose: use 20% of intubating dose, 20 mg intravenously or consider intubating dose if rapid sequence intubation may be planned.

Serious Pediatric Risks

- There have been rare reports of acute rhabdomyolysis with hyperkalemia followed by ventricular dysrhythmias, cardiac arrest, and death after the administration of succinylcholine to apparently healthy children who were subsequently found to have undiagnosed skeletal muscle myopathy, most frequently Duchenne's muscular dystrophy.
- Rescue from laryngospasm and facilitation of emergent intubation is still performed primarily with succinylcholine, but alternatively, increasing the depth of anesthesia with propofol or a volatile anesthetic agent (Sevoflurane) may be considered. Rocuronium may also be considered as an alternative to succinylcholine.

Rocuronium (Zemuron®)

- Non-depolarizing muscle relaxant that works at the cholinergic receptor.
- Has a much faster onset of action than other non-depolarizing agents, especially when

used in higher doses, it is almost comparable with succinylcholine.

- *Clinical Use:*
  - Intubation dose: 0.45–0.6 mg/kg IV bolus.
  - Rapid sequence intubation: 0.6–1.2 mg/kg IV bolus.
- *Reversal Agent*
  - Sugammadex, a cyclodextrin, is the first selective relaxant-binding agent; it exerts its reversal effect by forming tight complexes in a 1:1 ratio with steroidal non-depolarizing agents (e.g., rocuronium).

References

1. Rollert MK, Busaidy K, Krishnan D, Van Heukelom E. Parameters of care: AAOMS clinical practice guidelines for oral and maxillofacial surgery (AAOMS ParCare) Sixth Edition 2017. YJOMS. Am Assoc Oral Maxillofac Surg. 2017;75(Supplement):e34–49.
2. Gross J, Bailyer P, Connis R, Cote C, Davis F, Epstein B, et al. Practice guidelines for sedation and analgesia by non-anesthesiologists. Anesthesiology. 2002;96(4):1004–17.
3. Wijeysundera DN, Sweitzer B-J. Chapter 38 – Preoperative evaluation. Miller's Anesthesia, Eighth Edition. Philadelphia, PA: Elsevier; 2017. p. 1–78.
4. Apfelbaum J, Agarkar M, Connis R, Cote C, Nickinovich D, Warner M. Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures an updated report by the American Society of Anesthesiologists task force on preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration. Anesthesiology. 2017;126:376–93.
5. Langeron O, Amour J, Vivien B, Aubrun F. Clinical review: management of difficult airways. Crit Care. BioMed Central. 2006;10(6):243.
6. Graham DB, Eastman AL, Aldy KN, Carroll EA, Minei JP, Brakenridge SC, et al. Outcomes and long term follow-up after emergent cricothyroidotomy: is routine conversion to tracheostomy necessary? Am Surg. 2011;77(12):1707–11.
7. Hart K, Thompson S. Emergency cricothyrotomy. Atlas Oral Maxillofac Surg Clin NA. Elsevier Inc. 2010;18(1):29–38.
8. Apfelbaum JL, Caplan RA, Nickinovich DG, Hagberg CA, Benumof JL, Berry FA, et al. Practice guidelines for the management of the difficult airway: an updated report by the American Society of Anesthesiologists task force on management of the difficult airway. Anesthesiology. 2013;118:251–70.
9. Manifold C, Davids N, Villers L, Wampler D. Capnography for the nonintubated patient in the emergency setting. J Emerg Med. Elsevier Ltd. 2013;45(4):626–32.
10. Dickerson DM, Apfelbaum JL. Chapter 37 – Outpatient anesthesia. In: Basics of anesthesia. 7th ed. Philadelphia, PA: Elsevier Inc.; 2017. p. 24.
11. Strauss R, Noordhoek R. Management of the difficult airway. Atlas Oral Maxillofac Surg Clin NA. Elsevier Inc. 2010;18(1):11–28.