AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
SCIENTIFIC ASSEMBLY
1999

Advanced Airway Techniques (Prerequisite to lab)

In the setting of a failed intubation attempt, alternative approaches are vital. The lecturer will present a focused description of the following techniques: cricothyrotomy, lighted stylet intubation, tactile intubation, retrograde intubation, fiberoptic intubation, transtracheal jet ventilation, and use of the Bullard laryngoscope. A discussion of the use of the Combitube, percutaneous translaryngeal (PTL) airway and laryngeal mask airway will be included. (This course is required to attend the Advanced Airway Techniques Lab.)

- Discuss specific airway management alternatives in the setting of difficult intubation.
- Explain the techniques of cricothyrotomy, lighted stylet intubation, tactile intubation, retrograde intubation, fiberoptic intubation, transtracheal jet ventilation, and use of the Bullard laryngoscope.
- Compare and contrast the use of the Combitube, percutaneous translaryngeal (PTL) airway, and laryngeal mask airway.

MO-31
Monday, October 11, 1999
1:30 PM - 2:25 PM
Room # N227
Las Vegas Convention Center

FACULTY

Michelle Blanda, MD, FACEP

Associate Professor, Northeastern Ohio Universities College of Medicine, Rootstown, Ohio; Research Director/Attending Physician, Akron City Hospital, Summa Health Systems, Akron, Ohio

James E Manning, MD, FACEP

Associate Professor, Emergency Medicine, Surgery and Anesthesiology, University of North Carolina School of Medicine, Chapel Hill, North Carolina

American College of Emergency Physicians

1998 Scientific Assembly

Advanced Airway Techniques
SU-31

Instructor(s)
James E. Manning, MD, FACEP
Michelle Blanda, MD, FACEP

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Advanced Airway Techniques

SU-31

2 Hours

Faculty: Michelle Blanda, MD, FACEP; James E. Manning, MD, FACEP

Airway management is one of the most challenging aspects of emergency medicine. This course will discuss techniques for cricothyrotomy, lighted stylet intubation, fiber optic intubation, retrograde intubation, transtracheal jet ventilation, and insertion of a PTL airway. *(This course is required to attend the Advanced Airway Techniques Lab).*

- Discuss airway management alternatives in the setting of difficult intubation.

- Explain the techniques of cricothyrotomy, lighted stylet intubation, tactile intubation, retrograde intubation, fiberoptic intubation, transtracheal jet ventilation, and insertion of a PTL airway.

Advanced Airway Techniques Lab

James E. Manning, M.D., FACEP
Michelle Blanda, M.D., FACEP

I. Course Description

This is a practical skills lab course designed to give participants the opportunity to evaluate and practice performing airway management techniques. The indications, contraindications, techniques, advantages and limitations of alternative airway techniques will be covered.

II. Course Objectives

1. Discuss airway management alternatives in the setting of difficult intubation
2. Discuss the technical aspects of various alternative airway management techniques
3. Practice performing the alternative airway techniques discussed
4. Briefly discuss rapid sequence induction, capnometry and oximetry

III. Introduction

Airway management is one of the most crucial aspects of emergency medicine. The spectrum of acute airway disorders confronted in emergency medicine practice requires that emergency physicians be both knowledgeable and skilled in all aspects of acute airway management.

This course assumes that the participant is knowledgeable and experienced in routine endotracheal intubation techniques. The focus of this course will be on alternative techniques, both invasive and noninvasive, which may be useful options in clinical situations which preclude routine endotracheal intubation or make it very difficult.

The frequency of "difficult" intubations is not clear. This is due in part to how one defines "difficult" and the skill of the individuals making the determination. Reports in the anesthesia literature suggest that 6-18% of intubations by anesthesiologists are "difficult". Though it is reasonable to suspect that the percentage is higher in the more acute and less controlled environment of the emergency department, the precise percentage is less important than the ability to distinguish the routine from the difficult. Since difficult cases are not always predictable, the physician must always be prepared.

Several factors may predispose to difficult intubation. Suboptimal standard technique can make an otherwise routine intubation difficult. The most common mistake made during intubation is "cranking back" on the laryngoscope handle in order to lever the tip of the blade to provide better visibility. Though this maneuver may improve glottic visualization, it restricts the intubator's ability to manipulate the tube by limiting the size of the oral opening and it jeopardizes the teeth. Lifting the laryngoscope and blade upward and forward both improves glottic visibility and increases the oral opening allowing more room for manipulating the endotracheal tube. Anatomic variations which may predispose to difficult intubations include: short, thick mandibles; short, thick/fat "bull" necks; narrow mouth opening; large tongue; dental anomalies (protruding teeth); limited range of motion of the cervical spine; and congenital abnormalities (eg, scoliosis). A myriad of diseases can affect the anatomy, mobility and patency of the head and neck

area including temporomandibular joint disorders, degenerative cervical spine disease, trismus, malignancies, airway edema and foreign bodies. Patients that are combative, agitated, or actively seizing add motion to the task. Trauma is probably the major factor leading to difficult intubation. Head trauma patients require careful intubation to limit intracranial effects. Maxillofacial and neck trauma can directly compromise the airway and make accessibility nearly impossible. Bleeding frequently obscures vision and trauma patients are frequently agitated. In the majority of trauma patients, the potential for associated cervical spine injury precludes optimal neck positioning for intubation.

There are several alternatives, modifications and adjuncts which have been reported:

(1) Changing laryngoscope blades
(2) Endotracheal tube stylet
(3) Magill forceps
(4) Directional tip control tubes
(5) Blind orotracheal passage based on landmarks
(6) Use of an assistant
(7) Special laryngoscope blades
(8) Guiding stylets
(9) Lighted stylets
(10) Tactile orotracheal intubation
(11) Pharyngeo-tracheal lumen (PTL) airway
(12) Esophageal-tracheal combitube (ETC) airway
(13) Standard nasotracheal intubation
(14) Tactile nasotracheal intubation
(15) Translaryngeal guided or "retrograde" intubation
(16) Fiberoptic endotracheal intubation
(17) Laryngeal mask airway (LMA)
(18) Bullard laryngoscope
(19) Percutaneous transtracheal ventilation (PTV)
(20) Surgical cricothyrotomy
(21) Percutaneous tracheostomy
(22) Surgical tracheostomy

IV. Noninvasive Modifications, Adjuncts and Temporary Measures to Assist Intubation

Changing Laryngoscope Blades:
Switching the size or type (straight vs. curved) of laryngoscope blade may allow for better glottic visualization. Straight blades are recommended with over-riding teeth, a very floppy epiglottis, and for intubating small children.

Endotracheal Tube Stylet:
Stylets are commonly used to give the tube greater rigidity and allow greater curvature of the tube for reaching the more "anteriorly" situated larynx. The rigid stylet should never extend beyond the tip of the tube. In patients with glottic edema (e.g., burn patient) the tip of the endotracheal tube with a rigid stylet may not enter the glottic opening easily. In such a case, the end of the tube can sometimes be placed at the opening and threaded over the stylet.

Magill Forceps:
Although designed for nasotracheal intubation, they may also be used to direct a tube during orotracheal intubation.

Endotracheal Tube with Directional Tip Control:
These endotracheal tubes (Endotrol tubes) allow the intubator to alter the distal curve of the tube as needed during insertion. These tubes have the advantage of avoiding delays in intubation caused by having to readjust the tube curve.

"Blind" Orotracheal Passage based on anatomical landmarks:
Frequently during laryngoscopy the only structure seen is the epiglottis. The endotracheal tube can often be passed successfully by sliding the end of the tube along the under surface of the epiglottis and through the glottic opening. This is much like directing the tube superior to the arytenoids when these are the only structures of the larynx seen.

Use of an Assistant:
An assistant can be used to remove most of the physical strain frequently associated with difficult intubations. The assistant retracts the laryngoscope with the intubator's guidance until adequate glottic exposure is attained and then holds the scope steady. This could free up both hands of the intubator to manipulate the tube and use Magill forceps.

Special Laryngoscope Blades:

Laryngoscopes with mirrors and prisms attached allowing visualization of the glottis have been described but not widely used. More recently laryngoscope blades with fiberoptic components have been developed and may be useful.

Guiding Stylets:

In cases where the glottic opening can be seen but endotracheal tube insertion is difficult, passing a smaller guide through the glottis initially may facilitate tube insertion. Devices used successfully for this purpose include suction catheters, tracheal tube exchangers over stylet wires, and specially designed guides with distal directional control.

Lighted Stylets:

A lighted stylet or "light wand" is a transillumination technique for blind orotracheal or nasotracheal intubation. The light at the tip of the stylet is positioned within 0.5 cm of the end of the endotracheal tube (a 90^{o} angle is placed 4-6 cm from the end of the tube when using the rigid stylet). The tube is guided by observing the anterior neck for transillumination through the soft tissue. A bright red glow in the midline at the level of the larynx indicates proper guidance of the tube. If the bright red glow is off on the midline, the tip of the tube is in the pyriform sinus on the same side. A dull diffuse glow represents passage of the tube into the esophagus. An advantage of this technique is the lack of head and neck manipulation. Bright lighting limits this technique due to difficulty seeing the stylet light.

Tactile Orotracheal Intubation:

Intubation can be performed by palpating the epiglottis with the index and middle fingers. These fingers guide the tube under the epiglottis and into the trachea. A stylet should be used to provide a 90^{o} angle 4-6 cm from the tip of the tube. Advantages include: rapidity (when experienced), no special equipment and no movement of the head and neck. The obvious disadvantage is the need for a bite block or an edentulous patient in order to avoid being bitten.

Pharyngeo-Tracheal Lumen, Esophageal-Tracheal Combitube and Esophageal Obturator Airways:

Though designed for pre-hospital care use, these airways may provide adequate ventilation as a temporizing measure until a more secure airway can be obtained. EOAs are widely used by emergency medical personnel. The pharyngeo-tracheal lumen (PTL) and Combitube airways have two cuffed tubes. If the longer tube passes blindly into the trachea, it is used as an endotracheal tube. If the longer tube passes into the esophagus, the shorter tube is used to ventilate the lungs similar to the EOA. These devices potentially avoid the problem of accidental tracheal intubation which may occur with an EOA. However, the complexities of these airways, especially the PTL, make careful training necessary.

Standard Nasotracheal Intubation:

Patients requiring less emergent intubation are commonly intubated nasotracheally. However, the nasotracheal route may also be used in more emergent settings where orotracheal intubation would be difficult. Relative contraindications include facial fractures and coagulopathies. This is a reasonable alternative but the intubator's experience with this technique is clearly a major factor. Cricoid pressure may also facilitate nasotracheal intubation by decreasing the possibility of esophageal placement. Devices to enhance breath sound detection are available.

Tactile Nasotracheal Intubation:

In edentulous or unconscious patients the index and middle fingers may be placed in the oropharynx to help guide a nasotracheal tube. This is similar to tactile orotracheal intubation.

Laryngeal Mask Airway:

This device, usually referred to as an LMA, consists of a tube resembling an endotracheal tube with a distal mask structure designed to form a seal around the glottic structures in the hypopharynx. Experience with this device in emergency airway situations is growing and suggests that this may be a very useful temporary measure until a more secure airway can be obtained. The original devices were reusable and fairly expensive. Disposable LMAs are now available.

Bullard Laryngoscope:

This device is a rigid curved laryngoscope with an optical device that provides a view at the tip of the laryngoscope. This allows for better visualization of the glottis during difficult intubations. The endotracheal tube is attached to the Bullard laryngoscope in a manner that allows tube insertion while visualizing the glottis via the optical device.

V. Fiberoptic-Assisted Endotracheal Intubation

The use of fiberoptic instruments for difficult intubations has been well established by anesthesiology. However, emergency department use has been limited. With adequate training, fiberoptics offer a versatile technique for dealing with many difficult airways.

INDICATIONS: settings where fiberoptics might be a useful alternative

* cervical spine trauma - limits neck movement
* laryngotracheal trauma - assessment of injury severity & limitation of further injury
* cervical hematoma - due to anatomic distortion of the airway
* airway foreign body - only in cases without significant obstruction
* thermal inhalational injuries - allows assessment of thermal injury also
* mild/moderate agitation - may be able to avoid neuromuscular blockade, if desired
* seizures - may be able to avoid neuromuscular blockade
* when standard techniques have been unsuccessful due to inadequate visibility

CONTRAINDICATIONS: relative contraindications or likely that fiberoptics will fail

* apnea/agonal respirations - unless highly skilled, due to time required to perform
* heavy bleeding, secretions or vomitus which cannot be cleared - obscures vision
* severe agitation - due to technical difficulty
* complete upper airway obstruction

TECHNICAL ASPECTS:

* Set-up: scope, light source, bite block (if attempting orally), defogging agent
* When advancing the scope, keep airway lumen, glottic opening and tracheal lumen centered in the visual field. Anatomic structures in the periphery of the field are lost visually with advancement of the scope.
* Anatomic structures appear further away than they really are - telescoping effect
* The tip of the scope is adjusted by the manipulating the control lever and rotating the scope around its long axis - it is an eye-hand coordination skill like a video game
* Passing the scope vs. the ETT first into the hypopharynx is a judgment call based on the clinical situation. If there is blood in the airway, passing the ETT into the hypopharynx first may protect the scope from loss of visual field. If no bleeding is present, passing the scope first into the trachea is probably the best option.
* The ETT is advanced using the scope as a stylet. If the ETT hangs up at the glottic opening, ease the tube back slightly, rotate the ETT 90^{o} and attempt to pass again.

LIMITATIONS:

* time required to perform (generally 1-5 minutes, depending on experience & skill)
* visualization is completely obscured by blood, vomitus and heavy secretions

Several types of fiberoptic scopes exist varying in length, diameter, stiffness, and suction capability. These are generally classified as fiberoptic bronchoscopes, laryngoscopes or nasopharyngoscopes. A scope used for intubation should be long enough to reach well into the trachea. Nasopharyngoscopes generally only reach just past the vocal cords and are thus, not optimal. Laryngoscopes have a smaller diameter than bronchoscopes and thus will pass through the nares more easily and will accommodate smaller endotracheal tubes. Laryngoscopes are also more stiff and less likely to kink than bronchoscopes during intubation. The suction port can be used to clear thin secretions or to administer high-flow oxygen (which may help clear the visual field and promote oxygenation during the procedure).

VI. Translaryngeal Guided ("Retrograde") Intubation

INDICATIONS: clinical settings where it is an alternative

* bleeding, secretions or vomitus in the upper airway obscuring glottic visualization
* inability to orally or nasally intubate using standard techniques
* an alternative to surgical cricothyrotomy

CONTRAINDICATIONS:

* complete upper airway obstruction (absolute)
* severe trauma to the larynx or laryngotracheal separation (relative / absolute)
* soft tissue infection or abscess over the cricothyroid area (relative)
* coagulopathy (relative)

TECHNIQUE:

1. Identify the cricothyroid membrane

2. Insert a 16-18 gauge needle directing the needle at a 30-40^{o} angle cephalad
   - a through-the-needle catheter or, preferably, a soft-tipped guide wire

3. The guide is passed retrograde from the larynx to the oral cavity

4. The guide is secured at the skin over the cricothyroid membrane with a hemostat

5. The guide is threaded into the distal side hole (Murphy's eye) of an endotracheal tube and out the proximal end.

6. The tube is then passed along the guide into the larynx while the guide is held taut

7. The guide is then either cut or pulled through the cricothyroid membrane and removed through the proximal end of the ET tube
   - mild to moderate pressure must be held on the ET tube so that when the guide is released the tube will move down through the larynx and into the trachea and not fall back into the hypopharynx.

8. The ET tube is advanced into the trachea.

* A modification of this technique provides for oxygen flow through the needle penetrating the cricothyroid membrane while the rest of the procedure is performed.
* Another modification involves the placement of a flexible stylet through the ET tube into the distal trachea just prior to releasing the guide wire. This may help prevent the ET from falling back into the hypopharynx

LIMITATIONS:

* If the ETT falls into the hypopharynx at guide release, one must start over at step 1
* Optimally, the guide needs to be long enough to pass well out of the mouth. Most guidewires in vascular kits are barely long enough to attempt this technique.

VII. Percutaneous Transtracheal Ventilation (PTV) or Needle Cricothyrotomy

INDICATIONS: clinical settings where it is an alternative

* Inability to orally or nasally intubate
* An alternative to cricothyrotomy

CONTRAINDICATIONS:

* Complete airway obstruction (recent debate, especially if large catheter used)
* Coagulopathy (relative)

TECHNIQUE:

1. Identify the cricothyroid membrane

2. Insert a 12 ga - 16 ga over-the-needle catheter at a 30-45 degree angle caudally

3. Aspirate with a syringe during insertion; air return indicates the needle tip has entered the laryngotracheal lumen

4. Thread the catheter in completely (to the hub of the catheter)

5. Connect the catheter tip to a pressurized oxygen apparatus capable of delivering a pressure of approximately 50 psi

6. Provide one second inflations at a rate of approximately 12 per minute

* An alternative is to use a Seldinger catheter introducer set, such as an 8.5 Fr. introducer commonly used for pulmonary artery catheters. The needle can be used to make the initial puncture and the guidewire inserted securely into the distal trachea. The catheter is then inserted over the wire using the dilator. The 8.5 Fr. catheters have been shown to provide some exhalation and have been used successfully in models of complete airway obstruction

* If a high pressure oxygen source is not available, an oxygen-regulator system with the flow rate turned to maximum (generally 15 L/min) can be used though less optimal.

* If a high pressure oxygen source is not available, another alternative is to attempt to use a bag-valve apparatus connected to the catheter.
    - The proximal connector of an 8.0 ETT will fit tightly inside a 3 cc syringe
    - The proximal connector of a 3.0 ETT will fit into a catheter hub

LIMITATIONS:

* In general, this is a temporary procedure until a more secure airway can be attained
* Oxygenation can only be maintained for about 30 minutes due to the lack of adequate ventilation and progressive hypercapnea

VIII. Surgical Cricothyrotomy

INDICATIONS: clinical settings where it is an alternative

* severe maxillofacial trauma preventing oral intubation
* known unstable cervical spine fracture
* laryngotracheal trauma except for tracheal transection
* complete upper airway obstruction
* inability to secure the airway by other intubation techniques

CONTRAINDICATIONS:

* pediatric patients less than 12 years old
* laryngotracheal separation or tracheal transection

TECHNIQUE:

1. Locate cricothyroid membrane
   - stabilize the larynx, this can be done by bracing the laryngeal cartilage from above with the thumb and middle finger while maintaining identification of the position of the cricothyroid membrane with the index finger

2. Initial skin incision is a reasonable option
   - individual patient anatomy may dictate this decision
   - a midline, vertical incision (3-4 cm) or a horizontal incision over the cricothyroid membrane

3. Transverse (horizontal) incision through the lower part of the cricothyroid membrane, just above the cricoid cartilage

4. Insert Trousseau dilator, tracheal hook, hemostat, or blade handle
   - do not lose control of the opening made

5. Insert a tracheostomy tube (a #4 is appropriate for an average adult) or an endotracheal tube (a 6.0mm is adequate for an average adult)

6. Secure the airway

Cricothyrotomy is an emergency procedure which is guided by palpation of the anatomy. When indicated, it must be performed rapidly and it can usually be completed in less than thirty seconds. **It is a procedure guided by "feel", <u>not</u> by "sight".** The time required to dissect the neck tissues adequately to visualize the cricothyroid membrane would likely require several minutes and such a time delay would almost certainly be detrimental to the patient.

LIMITATIONS:

* severe laryngotracheal trauma, cervical hematoma or swelling make it very difficult
* cricothyrotomy is useless in complete tracheal transection or tracheal foreign body

IX. Airway Management in Trauma

Head Trauma

Head trauma patients frequently pose airway management problems for the emergency physician. Multiple trauma, including potential cervical spine injuries, are the rule rather than the exception. Brain injury with intracranial hypertension is a major concern. Initial management involves securing the airway to: (1) protect against aspiration, (2) maintain oxygenation, and (3) allow therapeutic hyperventilation.

However, securing an airway in such patients can be difficult and have adverse effects. Patients may be uncooperative due to fear, semiconscious state, or drugs/alcohol. The cervical spine must be immobilized until radiographically cleared. Unfortunately, these patients often require immediate airway control without the ability to do x-rays first. The laryngeal stimulation that occurs during intubation can be detrimental in such patients causing coughing and reflex sympathetic outflow resulting in (1) increased BP and tachycardia, and (2) elevation in ICP.

Therefore, various measures are taken to try to blunt these reflex responses:

* Topical anesthesia - Lidocaine (viscous or solution) applied to the oropharynx and nasopharynx
* Translaryngeal anesthesia (not widely used)
* Intravenous lidocaine 1.0-1.5 mg/kg
* Rapid Sequence Induction

Maxillofacial Trauma

Maxillofacial injuries can make airway management tremendously difficult. Deformity of the face due to fractures, swelling, hematomas, and loss of normal airway structural support make intubation very tricky. These same injuries may make bag-valve-mask ventilation as temporizing measure either very difficult or completely ineffective. Of course, associated cervical spine injury once again must be considered. Bone fragments, avulsed soft tissue, and teeth can act as foreign bodies. Acutely evolving airway obstruction is a major concern. Airway management options include:

* Standard orotracheal intubation
* Tactile orotracheal intubation
* Lighted stylet intubation
* Translaryngeal guided intubation.
* Fiberoptic endotracheal intubation
* Percutaneous transtracheal ventilation
* Cricothyrotomy
* Tracheostomy

Nasotracheal intubation is discouraged in maxillofacial trauma due to the potential for associated basilar skull fractures. An endotracheal tube could potentially pass into the cranial vault. Also, an increased incidence of meningitis has been reported in nasotracheally intubated patients with basilar skull fractures. Fiberoptic endotracheal intubation through the nasopharynx is an option which will prevent intracranial tube passage. Its use in this situation becomes a judgment call based on the individual case. If attempts at endotracheal intubation fail, PTV or cricothyrotomy is indicated.

Cervical Spine Trauma

The potential for cervical spine injury exists in virtually all cases of blunt head, neck, maxillofacial, and multiple trauma. Penetrating trauma is far less likely to cause an unstable injury, but it remains a possibility (especially with high energy ballistic injuries)

Obviously, the airway management goal is to secure the airway with the least possible cervical spine movement. If the patient's airway is stable enough to permit a cross-table lateral C-spine radiograph to be done, this should precede any intubation attempt. If the lateral x-ray is normal, an unstable C-spine injury is unlikely but not completely ruled out. Furthermore, the time delays associated with getting a lateral C-spine x-ray may not be inconsequential. In cases of significant trauma or when the time delay for an x-ray would be detrimental to the patient, the most prudent course of action is to cautiously intubate with as little movement of the neck as possible.

The most widely recommended technique is presently orotracheal intubation with in-line immobilization (NOT TRACTION). Nasotracheal intubation, if not contraindicated, is another acceptable method though its popularity has diminished over the past several years. Other less widely used methods which require little or no neck movement and are acceptable options include:

* Tactile orotracheal intubation
* Lighted stylet intubation
* Translaryngeal guided intubation
* Fiberoptic endotracheal intubation
* Percutaneous transtracheal ventilation

Laryngeotracheal Trauma

Laryngotracheal trauma is relatively uncommon due to the protection afforded by the face and chest. It is most commonly due to blunt trauma. Symptoms may be subtle and significant injuries can be overlooked, especially in the setting of multiple trauma. Patients may have an apparently stable airway hours after the insult and then suddenly deteriorate. If laryngotracheal trauma is suspected, thorough evaluation and careful monitoring are indicated. The most common injury to the larynx is a transglottic fracture from a direct right angle blow. Laryngotracheal separation most frequently occurs as a result of "clothesline type" injuries. Cervical trachea fractures are usually transverse through the tracheal rings. With complete transection, the lower trachea can retract distally into the thorax.

SIGNS & SYMPTOMS OF LARYNGOTRACHEAL TRAUMA:

* Subcutaneous emphysema
* Crepitus
* Airway obstruction
* Abnormal voice
* Hemoptysis
* Altered anatomy

Indirect or direct laryngoscopy are useful diagnostically

AIRWAY MANAGEMENT IN LARYNGOTRACHEAL TRAUMA:

Tracheostomy is clearly ultimately indicated in cases of significant laryngotracheal trauma. There is, however, some debate as to whether it should be the initial airway control procedure or if initial endotracheal intubation is acceptable. Some authors argue that intubation may cause further damage to the injured airway and recommend immediate tracheostomy. However, others suggest that initial intubation secures the airway and allows for a less hurried and more carefully performed tracheostomy. There are several case reports where such patients were successfully intubated emergently with adequate airway control. If intubation is attempted, some authors suggest using a smaller tube (e.g., 6.0-7.0). Fiberoptic laryngoscopy and intubation might be useful in managing such cases since the airway could be assessed visually for the extent of injury and then intubated at the same time.

Vascular Neck Trauma

Significant vascular injury in the neck can lead to hematomas which threaten to compress the airway. Such injuries can create a situation where both intubation and cricothyrotomy are technically very difficult. This makes the use of neuromuscular blockade hazardous. Appropriate management of such cases involves early intubation if there is an expanding hematoma. Emergency tracheostomy may be indicated if intubation is difficult.

Thoracic Tracheal and Bronchial Trauma

Thoracic tracheal injuries are usually posterior longitudinal tears within a few centimeters of the carina. Air can dissect from the tracheal defect into the mediastinum, pleural space, and retroperitoneum. Half of bronchial tears occur in the mainstem bronchi within 2.5 cm of carina. Bronchial tears can result in bronchopleural fistula which is an indication for a double-lumen tube.

Inhalational Injuries

Thermal inhalational injuries involve mainly the upper airway. They most commonly occur in enclosed spaces where temperatures are especially high. Examination for potentially significant inhalational injury should include looking for:

* facial burns
* singed nasal hair
* hoarseness
* pharynx - dry, red, blistered, soot

Examination of the pharynx is most important and most accurate. Flash fires or explosions often cause facial burns and singed facial/nasal hair without resulting in oropharyngeal or pharyngeo-tracheal burns. These cases require careful exam before the need for airway intervention is dismissed. Early intubation is indicated when significant airway burns are suspected. This is because progressive edema is likely to produce life-threatening airway compromise and at that point the airway is much more difficult to secure.

X. Rapid Sequence Induction, Capnometry and Oximetry

Rapid Sequence Induction

RSI involves the use of neuromuscular blocking agents and sedative/hypnotic agents to facilitate intubation and limit the potential adverse effects of laryngoscopy and intubation. Use of such agents requires a thorough understanding of their pharmacology including indications, contraindications, dosage, duration of effects, and adverse effects.

Sedative/Hypnotic agents induce unawareness and may help limit increases in intracranial pressure in head trauma patients. Agents which can be used include barbiturates, nonbarbiturate hypnotics, benzodiazepines, opiates and dissociative agents:

- thiopental	- propofol	- ketamine
- methohexital	- midazolam	- morphine
- etomidate	- valium	- fentanyl

Neuromuscular blocking agents are used to induce complete paralysis; relaxing the upper airway musculature making laryngoscopy easier. There are two classes of these agents:

Depolarizers - succinylcholine (most commonly used due to its short duration of action, < 10 mins)
Nondepolarizers - atracurium, mivacurium, pancuronium, rocuronium, vecuronium

Sequential Steps in RSI Intubation:

1. Preparation: Preoxygenate with **100% O_2** (for 2 minutes if possible)
   Check all intubation equipment and endotracheal tube
   Have suction set up and running
   Surgical airway equipment at bedside
2. Premedication
   a. Consider **atropine** [in all children & in adults if bradycardia or a second dose of succinylcholine is required]
   b. **Subparalytic** defasciculating dose of **nondepolarizer** (eg, vecuronium, 0.01-0.015 mg/kg rapid IV)
      [given 1-3 minutes, preferably 3 mins if possible, prior to succinylcholine;
      preventing fasciculations may limit ICP increase with succinylcholine]
   c. **Lidocaine** 1.0-1.5 mg/kg slow IV
      [to blunt autonomic reflexes (increased HR, BP) & cough reflex associated
      with laryngoscopy which might result in an ICP increase --- efficacy is debated]
3. Sedation/Hypnosis - "if cardiovascular status permits"
   Thiopental (4-5 mg/kg), **methohexital** (1.0-1.5 mg/kg), **etomidate** (0.3-0.4 mg/kg) or **propofol** (2.5 mg/kg)
   [limits ICP increase in addition to providing sedation, but must be used cautiously or
   avoided in hypotensive & hypovolemic states, esp. thiopental & methohexital]
   or
   Benzodiazepines and/or opiates (eg, midazolam, fentanyl) [reasonable alternatives]
4. Cricoid pressure
5. Paralyze
   Succinylcholine 1.5 mg/kg rapid IV
   or
   Nondepolarizer (eg, vecuronium 0.1 mg/kg rapid IV; usually if succinylcholine is contraindicated;
   a subparalytic (priming) dose is not required - since no fasciculations)
6. Orotracheally intubate and confirm tube position (auscultation, capnometry & oximetry)

Capnometry

End-tidal CO_2 detection is a highly sensitive and specific determinant of tracheobronchial placement of the ETT. The two major limitations of this technology are the frequency of false negatives in cardiac arrest patients and the inability to distinguish tracheal versus bronchial ETT placement. It is a useful adjunct to be combined with auscultation.

Pulse Oximetry

Continuous oxygen saturation monitoring is useful in preparation for intubation and assessment of ETT placement. It is not as specific as capnometry and inaccuracy is not uncommon (hypotension, agitation, etc.). It is more useful than capnometry is assessing therapeutic interventions. It is a useful adjunct which should be used whenever possible.

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