Operative Techniques in Otolaryngology (2005) 16, 166-170

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Operative Techniques in Otolaryngology

FEATURE ARTICLES

Intubation techniques

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KEYWORDS
Difficult pediatric intubation;
Airway evaluation;
Laryngeal mask airway;
Fiberoptic intubation

Difficult pediatric intubation may be especially challenging because children are less likely to cooperate with awake intubation, and rescue strategies such as cricothyrotomy may not be feasible. Management strategies should include careful evaluation to determine a sequence of interventions appropriate for the individual, starting with simple measures and with advanced techniques such as fiberoptic intubation available. The laryngeal mask airway can often provide an adequate airway, and a conduit to definitive intubation.

The anesthesiologist often encounters children with sleep disordered breathing when they undergo procedures such as adenotonsillectomy for obstructive hypertrophy. Direct laryngoscopy and intubation are seldom difficult in these patients, but they may obstruct during inhalation induction of anesthesia, and extubation can be difficult if narcotics and benzodiazepines are administered too generously.

Difficult intubation and obstructive breathing are more common in children with dysmorphic syndromes, especially those with retrognathism or micrognathia. Intubation by direct laryngoscopy may not be possible, and hypoxia develops rapidly if a "can not mask, can not intubate" situation develops. Children with difficult intubation are especially challenging because they seldom cooperate with awake intubation, and establishing an emergency airway by cricothyrotomy is not the reliable rescue strategy it is in adults.[1]

Successful intubation and management of the challenging pediatric airway requires a strategic approach, including recognition and evaluation, and a sequence of interventions proceeding from simple to advanced intubation techniques, while avoiding steps such as muscle relaxation that may preclude awakening the patient when planned interventions are unsuccessful. This strategic approach is the basis of the Difficult Airway Guidelines, published by the American Society of Anesthesiologists.[2] A structured approach to difficult airway management has received further support from analysis of closed anesthesia malpractice claims, which show that many of the highest awards are associated with hypoxia from failed airway interventions.[3]

Assessing the difficult airway: The glottic view

Anesthesiologists routinely document intubation difficulty using the Cormack and Lehane[4] grade to describe the extent of glottic visualization by routine direct laryngoscopy (Figure 1). Grade I is a full view of the glottis, in grade II, the posterior commissure is seen, in grade III, only the tip of the epiglottis is visible, and, in grade IV, no glottic structures are seen. Most anesthesiologists and other endoscopists should be able to intubate patients with grade I and II airways by direct laryngoscopy. Grade III airways usually require special skills, including fiberoptic intubation, although careful positioning and laryngeal pressure may effectively reduce some to a grade II level. Grade IV airways require advanced skills, can be dangerous, and may be life threatening if not handled well.

Evaluation: Recognizing the difficult airway, evaluating the difficulty

Recognizing difficult airways

Most children with difficult intubation can be anticipated, either because they are well known to the care team

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1043-1810/$ -see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.otot.2005.09.008

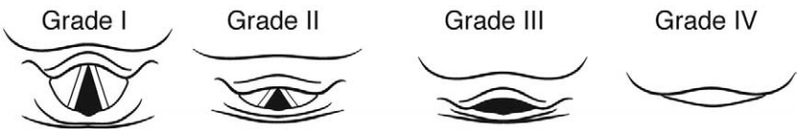

Figure 1 Cormack and Lehane grading scale (illustration modified from original).[4] Grade I: Full view of the glottis. Grade II: Only the posterior commissure is seen. Grade III: Only the tip of the epiglottis is visible. Grade IV: No glottic structures are seen.

for a past history of difficult intubation or because dysmorphic features identify them with one of the recognized syndromes associated with difficult intubation. These syndromes include the Pierre Robin syndrome, the Treacher Collins syndrome, hemifacial microsomia and Goldenhar syndrome, and the mucopolysaccharidoses. Difficult intubation may also occur unexpectedly in children with relatively normal facial structure and features. An airway examination should be included in the preoperative preparation of all patients to try to identify those at risk.

In children, observing the face from both the front and side can detect most potential difficult intubations. Examining the mouth while encouraging them to open it as far as possible assesses both mouth opening (the "interdental distance") and also reveals the palate. A restricted view of the palate is also associated with difficult intubation, especially in adults, and is widely known to anesthesiologists as the "Mallampati view" (Figure 2).[5,6] In normal patients, the tip of the uvula should be visible; intubation becomes more difficult as the tongue progressively obstructs the view, until only the hard palate can be seen.

The second screening test observes the face from the side to evaluate the chin and alignment of the lower teeth in relation to the upper teeth. A small hypoplastic chin is a warning that merits further evaluation. Cervical spine and atlanto-occipital mobility can also be evaluated, asking the child to look up and down as far as possible.

Evaluation of the degree of difficulty

When a difficult intubation is predicted, it is helpful to assess the degree of difficulty, both to plan the primary and alternative strategies, and to ensure the presence of necessary resources. The difficult intubation is usually caused by a combination of features that together impair the line of sight to the glottis, although, occasionally, a single feature such as inability to open the mouth more than a few millimeters may prevent intubation by direct laryngoscopy. These features may be incorporated into a score that shows promise in predicting the degree of difficulty, and helps in preparing suitable equipment and people to treat the difficult intubation (Table 1).

The strategic airway plan

Management of the difficult airway in small children is inherently more difficult than in adults, who may not only accept awake intubation but also can be rescued more easily by percutaneous cricothyrotomy or tracheostomy. When a difficult pediatric airway is anticipated, it is wise to plan a sequence of airway examinations and interventions, leading to a successful outcome while avoiding maneuvers such as muscle relaxation that may lead to a "cannot intubate, cannot ventilate" situation. The plan may not include every conceivable airway strategy but should consider the individual patient's airway problem, the skills of the care team, and other resources, including availability of advanced equipment such as fiberoptic scopes.

Avoiding intubation

Sometimes, the smartest way to intubate the difficult airway is to "just say NO!" Some procedures, including imaging studies, are not painful and only require immobilization. If the patient cannot cooperate, sedation with propofol may allow the studies to be performed without airway instrumentation. A satisfactory airway can often be achieved by placing a roll under the shoulders to extend the neck. The propofol infusion can be slowly titrated or stopped if obstruction occurs, and ventilation is easily monitored using a nasal catheter to detect end-tidal carbon dioxide. Other procedures can be accomplished with regional anesthesia or

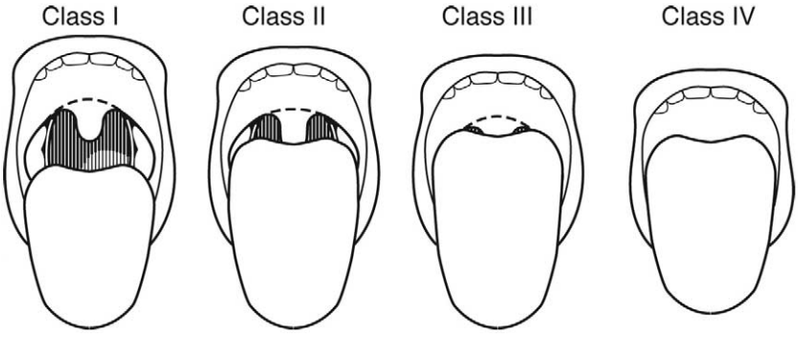

Figure 2 Mallampati classification (illustration modified from original).[5] Class I: The tonsillar pillars, soft palate, and uvula are visible. Class II: The soft palate and most of the uvula are seen, but the pillars and tip of the uvula are obscured. Class III: The soft palate and base of the uvula are visible. Class IV: The soft palate cannot be seen.

Table 1 Colorado Pediatric Airway Score (COPURway score)

	Points		Points
C - Chin		U - Uvula	
From side view, is chin:		Mouth open, tongue out, observe palate:	
Normal size?	1	Tip of uvula visible	1
Small, moderately hypoplastic?	2	Uvula partially visible, fauces	2
Markedly recessive?	3	Uvula concealed, soft palate visible	3
Extremely hypoplastic?	4	Soft palate not visible at all	4
O - Opening		R - Range	
Interdental distance between front teeth		Observe line from ear to orbit, estimate range of movement, looking up and down	
>40 mm	1	>120 degrees	1
20–40 mm	2	60–120 degrees	2
10–20 mm	3	30–60 degrees	3
<10 mm	4	<30 degrees	4
P - Previous intubations, OSA		Modifiers - add points for:	
Previous intubations without difficulty	1	Prominent front 'buck' teeth	1
No past intubations, no evidence of OSA	2	Very large tongue, macroglossia	1
Previous DI, or symptoms of OSA	3	Extreme obesity	1
DI - extreme or unsuccessful; emergency tracheotomy; unable to sleep supine	4	Mucopolysaccharidoses	2

Predictions:

Points	Intubation difficulty	Glottic view (Cormack and Lehane)[4]
5–7	Easy, normal intubation	1
8–10	More difficult, laryngeal pressure may help	2
12	DI, fiberoptic intubation less traumatic	3
14	DI, requires fiberoptic or other advanced methods	3
16	Dangerous airway, consider awake intubation, advanced methods, potential tracheotomy. (Patient with hypercarbia awake, severe obstruction)	4
16+	Scores >16 are usually incompatible with life without an artificial airway	

Abbreviations: DI, difficult intubation; OSA, obstructive sleep apnea.

with inhalation mask anesthesia. Although these techniques may be successful in skilled hands, they are but a primary strategy, and the anesthesiologist should have alternative plans ready for intervention if needed.

Laryngoscopy: Awake versus asleep

Children from approximately 12 months through 8 or 10 years of age rarely cooperate with awake intubation; when it is attempted, the larynx becomes a moving target, making intubation more difficult. These patients often return for further procedures, and previous traumatic experiences from awake intubation may hinder subsequent anesthetics. Awake direct laryngoscopy for neonates and infants with difficult intubation is appropriate, and may proceed to awake intubation if the larynx can be seen. A satisfactory view of the epiglottis and posterior commissure may reassure the anesthesiologist that inhalation anesthesia and direct laryngoscopy will be safe, whereas the lack of such a view may suggest that a more advanced approach will be needed.

For children older than 12 months, inhalation anesthesia with sevoflurane and 100% oxygen is considered safe for most difficult airways. The theory is that if airway obstruction occurs, the partial pressure of anesthetic in the brain will decrease quickly from redistribution, and the patients should wake up (breathing oxygen.) This theory is not a guarantee, and patients with extremely dangerous airways should be considered for awake intubation, regardless of age.

Direct laryngoscopy

Direct laryngoscopy relies on line of sight visualization from the endoscopist's eye to the glottis; experts learn to adjust the pressure and position of the laryngoscope while manipulating the upper airway to achieve the best view. Alignment of the axes of the upper airway and the larynx was traditionally emphasized, with flexion of the head on an extended neck, producing the "sniffing the morning air" position. In reality, all that is necessary is to retract those tissues that impinge on the direct view of the glottis. When the features that cause difficult intubation are recognized, they may be overcome using specific maneuvers. Starting from the larynx and working upwards, they are (Figure 3):

1. *Laryngeal pressure.* Direct pressure on the larynx can push the glottis back and improve visualization. The maneuver may be performed with the endoscopist's little finger or by guiding an assistant's hand. The pressure is usually more effective when directed against the thyroid rather than the cricoid cartilage, and "Backwards, Up-

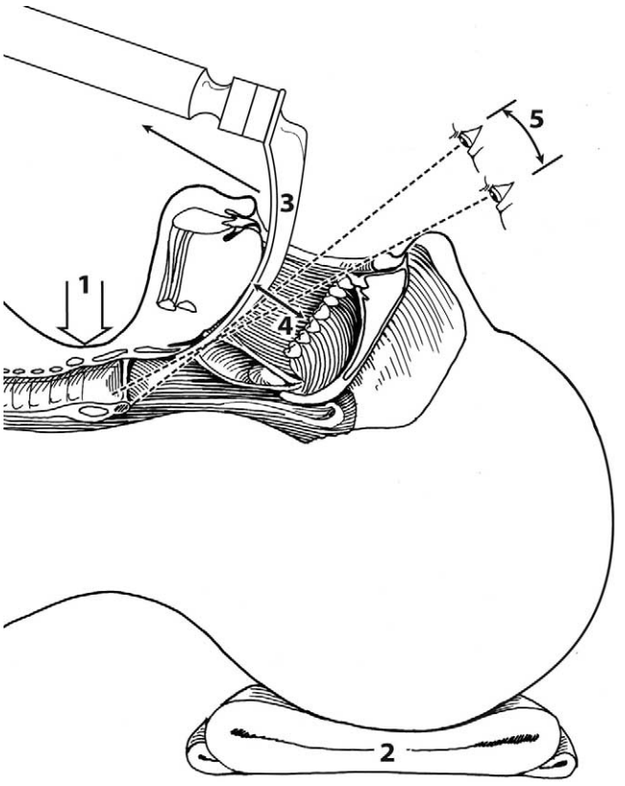

Figure 3 Maneuvers to improve the view of the glottis. (1) Laryngeal pressure. (2) Neck extension. (3) Tongue and soft tissue retraction. (4) Mouth opening. Sometimes the view may be improved by placing the laryngoscope at a gap in the upper teeth, or even through the left side of the mouth. (5) The observer's eye. The endoscopist's eye is usually over the child's face, even with the tongue retracted to the left.

ward, and Rightward Pressure," as described by the "BURP" maneuver[7] may be most effective.

2. *Neck extension.* The relatively large head of the child usually obviates the need for elevating the occiput, and simply pushing the occiput down or pulling the upper teeth and maxilla upwards may achieve optimal extension. Sometimes the "normal rules" do not work, and lifting the head up and down while performing direct laryngoscopy may suggest the best alignment.
3. *Tongue and soft tissue retraction.* Much of the endoscopist's skill is in the placement of the laryngoscope blade, to elevate and retract the soft tissues of the floor of the mouth away from the line of sight. Small changes in position may improve the view; the tip of the blade may sometimes be better in the vallecula, sometimes under the epiglottis. Changing from one style or size of blade to another may help. The author finds the Robertshaw style of blade can help in children with difficult intubation. The blade is relatively straight, with a slight distal curve and a very narrow flange. It can improve success in difficult circumstances, especially restricted mouth opening. Sliding the blade down the left side of the mouth may sometimes be better than the traditional right side, especially with facial asymmetry in hemifacial microsomia.
4. *Mouth opening.* Restricted mouth opening makes direct laryngoscopy difficult or impossible. Sometimes the view may be improved by placing the laryngoscope at a gap in the upper teeth, or even through the left side of the mouth. Removing teeth is generally frowned on, although, occasionally, performed deliberately or accidentally. A dental mouth gag can sometimes increase mouth opening, and deeper anesthesia or perhaps muscle relaxation may improve opening in the presence of trismus.
5. *The observer's eye.* The endoscopist's eye is usually over the child's face, even with the tongue retracted to the left. The anterior arch of the maxilla limits the view of the glottis, but the view can be improved by placing a long, narrow laryngoscope blade as far lateral to the back molars as possible. The observer can then lower his viewpoint to get a better view under the epiglottis. Because a long straight blade works best with this method, a bougie or tube change catheter may be placed through the larynx more easily than an endotracheal tube.

Direct laryngoscopy: Bougies and catheters

The intubationist usually places an endotracheal tube through the glottis when it is revealed by direct laryngoscopy, with an internal stylet to stiffen the tube if necessary. When the best view is poor and restricted, it is sometimes possible to place a small catheter through the cords and then slide the endotracheal tube over the introducer. In the United Kingdom, the gum elastic bougie is widely recommended as the first strategy for adult difficult intubation, in children, the smaller airway exchange catheters can be used the same way. They also have the advantage of allowing oxygen insufflation during the procedure.

Supraglottic airway devices

The classic laryngeal mask airway (LMA) has been in use for more than 20 years,[8] and is available in sizes for children and neonates, both in the reusable version and the disposable "LMA-Unique." There are several new supraglottic devices competing with the LMA for pediatric use, but the LMA still enjoys a reputation for its careful development and regulatory approval. The LMA has several advantages in difficult airway management. When intubation by direct laryngoscopy fails, the LMA can usually be placed successfully. Anesthesia and surgery may then proceed using the LMA to provide an acceptable airway and positive pressure ventilation, or the LMA may be used as a conduit to pass an endotracheal tube. There are even reports of LMAs being used to maintain the airway for several days.[9]

There are several ways to intubate using the LMA. The endotracheal tube can be passed blindly through the LMA into the larynx.[10] The "Fastrach LMA" is specifically designed to improve intubation success, but it is still not available in small sizes for children. Success is higher when a fiberoptic scope is passed through the LMA into the larynx. Once in the trachea, an endotracheal tube may be advanced over the scope into the larynx, and a tracheotomy can be performed without removing the LMA. If the LMA must be removed, the single endotracheal tube is so short

that other tricks must be used. A second endotracheal tube with a smaller diameter can be lodged into the proximal end of the first endotracheal tube so that the combined length ensures the distal tip stays in the trachea, while the proximal part of the assembly sticks far enough out of the LMA as it is withdrawn, until the first endotracheal tube can be grasped at the lips. Another method is to pass a long (125-cm J-tip) guidewire through the suction channel of the scope, which is then withdrawn. A small suction catheter is placed inside the endotracheal tube, and threaded together over the wire and into the trachea. The catheter stiffens the wire and reduces the risk of the endotracheal tube becoming caught on the glottis.

The LMA is a valuable resource when intubation by direct laryngoscopy fails, but placement may not be possible in some extremely difficult airways.[11] In these airways, the epiglottis lies against the posterior wall of the pharynx so closely that the advancing tip of the LMA fails to pass behind the epiglottis, and may actually press the lingual surface down onto the glottis, making airway obstruction worse.

Fiberoptic intubation

Fiberoptic endoscopy offers the best chance of accomplishing intubation when direct laryngoscopy fails to reveal the glottis, although the expertise and equipment are not always available. The endoscope is usually placed inside the endotracheal tube, which is advanced over the scope when the tip is just above the carina. With scopes available to fit through endotracheal tubes as small as 3 mm, fiberoptic intubation is available for all pediatric patients, although the smaller scopes are much more flexible and require more skill.

A camera improves performance by providing a larger, clear image and by enabling other team members to assist the endoscopist; some new intubation scopes have digital video chips at the distal end, and resolution is much improved. Success depends on learning to introduce the scope through the mouth or through the nose, keeping to the midline, and following the landmarks to the larynx. Anterior, the groove along the midline of the tongue leads to the epiglottis; posterior, the midline raphe in the palate appears as a pale white line, leading downwards to the uvula.

The flexible fiberoptic scope lacks the rigidity of metallic laryngoscopes, and cannot retract the tongue and soft tissues that obscure access to the larynx. Fortunately, there are several strategies that enhance performance in this situation. Simple maneuvers include extension of the neck and a chin thrust. The next step is to pull the tongue out of the mouth using a dry sponge, and if that fails, a malleable surgical ribbon retractor can be bent to a "hockey-puck" shape and used to lift the tongue forward. These retractors are available in various widths and can be extremely useful. A laryngoscope does not help in this situation. The blade is usually too long and obscures the glottis, and the direction of the applied force is too low to lift the tongue away from the back of the pharynx. Another strategy is to place an LMA and establish ventilation, and intubate the larynx with a fiberoptic scope, as described previously.

Other advanced methods

The flexible scope is the most versatile tool for the direct intubation, but there are other methods, including the lightwand, and rigid fiberoptic laryngoscopes of which the Bullard scope (ACMI Corp, Southborough, MA) is best known. Each of these requires skill and experience, but those who have achieved such skills can often intubate the difficult airway as rapidly as most others using the fiberoptic scope. These methods do have some advantages. The equipment is generally stiffer and, thus, able to push extraneous tissue out of the way, and they may be less susceptible to impaired vision from blood and secretions.

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