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Laryngospasm in anaesthesia

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Laryngospasm is a common and serious respiratory complication in anaesthetic practice which can be fatal if not diagnosed and treated timeously. This review will look at the definition, epidemiology, mechanism, risk factors, clinical presentation, differential diagnosis, prevention, treatment and complications of laryngospasm.

Definition

Literature provides multiple definitions for laryngospasm. Some clinical definitions regard laryngospasm as any unwanted muscular response of the larynx that produces partial or complete obstruction of the larynx,[1] while from an anatomical point of view, laryngospasm is seen as prolonged closure of the larynx in association with a ball-valve mechanism involving the intrinsic laryngeal muscles.[2]

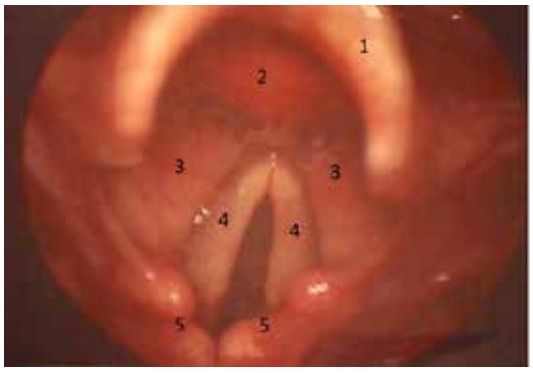
Epidemiology

The reported incidence of laryngospasm differs vastly. The overall incidence is said to be 0.87%.[1] The paediatric incidence is quoted as 1.7% by Olsson[1] and 0.1% by Burgoyne[3] with a higher incidence in infants of 2.82%. The reported incidence probably depends on the case mix of the reporting hospital,[4] experience of the anaesthetist (higher incidence amongst junior personnel or when substantial interruption of clinical work has occurred)[5] and the lack of consensus on the definition of laryngospasm. Underreporting probably also skews data, as reporting is not compulsory in all centers[5] and cases managed timeously often resolve quickly and remain unreported. It is likely that the incidence has declined with the use of propofol total intravenous anaesthesia and modern, non-irritant inhalational agents.[3]

Mechanism

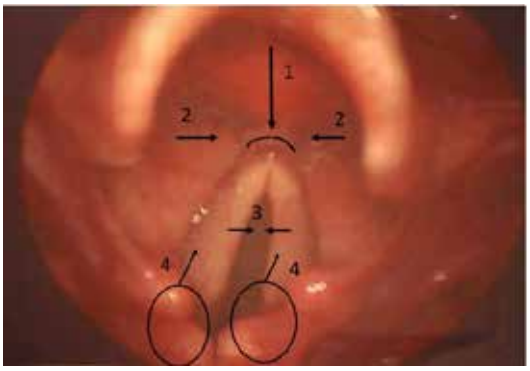
Laryngospasm is a protective airway reflex. The afferent leg of the reflex involves mechano-, chemo- and thermoreceptor stimulation of the supraglottic airway which results in activation of the internal branch of the superior laryngeal nerve. The sensory nerve supply to the subglottic airway is via the recurrent laryngeal nerve. Reflex adduction of glottic muscles follows through a vagal efferent pathway. The recurrent laryngeal nerve supplies all the intrinsic laryngeal muscles other than the cricothyroid muscle (which is supplied by the external branch of the superior laryngeal nerve). Laryngospasm is mediated through the lateral cricoarytenoid and thyroarytenoid muscles (adductors of the glottis) and the cricothyroid muscle (tensor of the vocal cords). Vagal nerve mediated apnoea, bronchoconstriction and bradycardia often accompany laryngospasm.[6] Laryngospasm occurs on two anatomical levels (Figure 1). False vocal cord closure with simultaneous anterior movement and backwards tilt of the arytenoids and posterior movement of the base of the epiglottis firmly close the larynx. The true vocal cords close at a lower level and posterior to the false vocal cords. Their closure is not mandatory for laryngospasm to occur, as is evident from the fact that laryngospasm is possible in bilateral vocal cord paralysis.[5] Hypoxia and hypercapnia eventually decrease brainstem impulses to the superior laryngeal nerve, resulting in decreased intensity of glottic closure and spontaneous cessation of laryngospasm as hypoxia and hypercapnia worsen.[7] Dangerous complications may however ensue (see below), and laryngospasm is best treated timeously.

Figure 1a: Normal airway anatomy
Photo credit: Daniel Simpson



1. Epiglottis
2. Base of the epiglottis
3. False vocal cords
4. True vocal cords
5. Arytenoid cartilages

Figure 1b: Mechanism of laryngospasm[5]



1. Base of the epiglottis moves posteriorly
2. False vocal cords contract
3. Vocal cords close (deeper level than 1,2 and 4)
4. Arytenoids move forward; tilt back

Causes and risk factors

Laryngospasm is usually caused by either airway stimulation (blood, secretions, foreign objects) or a light plane of anaesthesia resulting in inadequate central nervous system depression of airway reflexes.[8]

Risk factors can be divided into three categories (see Table I)

a. *Anaesthesia-related factors*

Insufficient depth of anaesthesia at induction or emergence is probably the most common cause of laryngospasm. When blood or mucus accumulate in the airway or suction catheters or laryngoscope blades are inserted into the airway at this point, laryngospasm is frequently elicited. Sodium thiopentone does not blunt the airway responses and, compared to propofol, the incidence of laryngospasm is increased.[9] Ketamine *per se* does not cause laryngospasm, but its tendency to increase secretions may indirectly result in spasm.[10] Intravenous maintenance of anaesthesia with propofol causes less laryngospasm than sevoflurane, probably due to the ability of propofol to blunt airway reflexes.[11] Of the inhalants, the highest incidence is seen with desflurane, then isoflurane, enflurane and lastly sevoflurane and halothane (equal incidence).[12,13] Sugammadex has been reported to cause tight glottic closure around two minutes after administration, which correlates with train-of-four ratios in excess of 0.9. This reportedly resolved after 2-3 minutes with the application of positive end-expiratory airway pressure (PEEP).[14,15] The use of laryngeal mask airways (LMA) is listed as an independent risk factor for laryngospasm, but studies do not state what proportion of patients were done with LMA, whether they were breathing spontaneously or assisted or whether the LMA was removed deep or awake.[4] Other studies found that laryngospasm occurred more on induction when LMAs were used and more on extubation when endotracheal tubes were used.[16]

b. *Patient-related factors*

The incidence of laryngospasm is higher in children and especially small babies.[17] Upper respiratory tract infections cause airway hyperactivity, increasing the risk of laryngospasm. This hyperactivity lasts 6 weeks after the infection.[18] More laryngospasm occurs in American Society of Anesthesiologists (ASA) class 3 and 4 patients compared to those of class 1 and 2, but emergency surgery does not seem to independently increase the risk of laryngospasm.[19] The incidence is increased in children with airway anomalies,[20] as well as in adult patients with anatomically long uvulas[21] or a history of choking during sleep.[22] Chronic smoking also increases airway reflex sensitivity and smokers are advised to abstain from smoking for at least 48 hours prior to surgery.[23] Passive smoking also increases airway reactivity. Gastroesophageal reflux is another risk factor for laryngospasm.[24]

c. *Surgery-related factors*

The type of surgery influences the incidence of laryngospasm. Tonsillectomy and adenoidectomy probably have the highest incidence with others like appendectomy, cervical dilation, hypospadia surgery and skin grafts also displaying an increased risk.[1]

In thyroid surgery, laryngospasm may occur either secondary to superior laryngeal nerve injury or due to hypocalcaemia following iatrogenic parathyroidectomy.[7,25] Oesophageal surgery could cause laryngospasm via stimulation of the distal afferent oesophageal nerves.[26]

Presentation of laryngospasm (see Table II)

Two clinical entities are commonly distinguished – partial laryngospasm (chest movement with stridor and limited bag movement disproportional to breathing attempts) and complete laryngospasm (silent chest movement, no bag movement and no ventilation possible).[8,27] The literature is however divided on the

Table I: Risk factors for laryngospasm

Anaesthesia-related	Insufficient depth of anaesthesia Airway irritation with inhalational agents, blood, etc. Sodium thiopentone (does not blunt airway responses) Ketamine induced secretions Desflurane, isoflurane, enflurane in awake patients Sugammadex LMA > ETT (on induction) ETT > LMA (on extubation)
Patient-related	Children Upper respiratory tract infections ASA class ≥ III Children with airway anomalies Chronic smoking (including passive smoking) Gastroesophageal reflux Long uvula; history of choking at night
Surgery-related	Airway surgery (Tonsillectomy and adenoidectomy) Appendectomy Genitourinary surgery (hypospadia, cervical dilatation) Thyroid surgery (SLN injury; hypocalcaemia secondary to iatrogenic parathyroidectomy) Oesophageal surgery

LMA = laryngeal mask airway; ETT = endotracheal tube; ASA = American Association of Anesthesiologists; SLN = superior laryngeal nerve.

existence of "partial laryngospasm". Some present endoscopic evidence that, during closure of the true vocal cords, passage of some air could occur through the posterior commissure, resulting in stridor which should not be seen as partial laryngospasm and only false cord closure is viewed as laryngospasm. True cord closure is possible prior to false cord closure (laryngospasm) or after laryngospasm has resolved. Laryngospasm is regarded as silent and stridor as a clinical sign of broken laryngospasm.[5] Other clinical signs of laryngospasm include a lack of airflow at the mouth or nose, intercostal retraction, tracheal tug, paradoxical breathing and late signs including desaturation, bradycardia and cyanosis.[28] In adults, severe strain against a closed glottis is often evident from engorged neck veins and vigorous movement of the body, resembling severe coughing efforts, albeit silent. In babies, desaturation is often the first or only sign (personal observation). Capnographic evidence of laryngospasm entails a lack or severe decrease in end-tidal CO_2 ($ETCO_2$).

Table II: Presentation of laryngospasm

Chest movement with limited airflow at the mouth or nose and limited bag movement
Silence or stridor
Body movements; engorged neck veins
Intercostal retraction
Tracheal tug
Paradoxical breathing
Desaturation
Bradycardia
Cyanosis
Absence of $ETCO_2$ on capnography

$ETCO_2$ = End-tidal carbon dioxide

Differential diagnosis (see Table III)

The differential diagnosis probably resembles the differential diagnosis of vocal cord dysfunction[29] and will include anaphylaxis, angioedema, tracheal stenosis, vocal cord polyps or other tumours, foreign bodies in the airway, vocal cord paralysis, laryngomalacia and tracheomalacia. Breath holding and reflex apnoea (especially in children) due to the Hering-Breuer reflex occur on over-inflation of the lungs. This will worsen when sustained high inflation pressure is administered to the airway, as is often the case during treatment of laryngospasm.[28] Vocal cord dysfunction (VCD), also known as paradoxical vocal cord motion (PVCM), is a condition where vocal cords paradoxically adduct during inspiration leading to stridor, wheezing and dyspnea. This occurs during emotionally stressful times and is a possible cause of postoperative stridor or laryngospasm. Treatment includes benzodiazepines and reassurance.[30] Residual muscle relaxants or opioids cause loss of upper airway tone with occlusion of the pharynx by the tongue. This should be excluded when stridor occurs in the recovery room. Although bronchospasm usually results in expiratory wheezing and not inspiratory stridor, bronchospasm and laryngospasm often co-exist, especially when triggered by airway stimulation during light plains of anaesthesia. Bronchospasm should therefore be excluded once laryngospasm has ceased.

Table III: Differential diagnosis of laryngospasm

Anaphylaxis
Angioedema
Tracheal stenosis
Vocal cord polyps or tumours
Foreign bodies in the airway
Vocal cord paralysis
Laryngomalacia
Tracheomalacia
Breath holding or reflex apnoea
Vocal cord dysfunction (VCD) or paradoxical vocal cord motion (PVCM)
Loss of upper airway tone
Bronchospasm

Prevention (see Table IV)

The incidence of laryngospasm is lower in the hands of experienced anaesthetists.[5] The use of premedication to decrease laryngospasm is controversial. Anticholinergic drugs reduce secretions and therefore reduce laryngeal irritation, but they display some undesirable side-effects. Their use should probably be limited to use in conjunction with ketamine or in patients known with increased secretions. Benzodiazepines decrease upper airway reflexes and may reduce laryngospasm. Although it will not prevent laryngospasm, some authors feel that N_2O should be omitted during preoxygenation as to ensure optimal oxygen reserve in case of laryngospasm or other difficulties.[31] Inhalational induction should be done with a non-irritating agent like sevoflurane or halothane and the patient should be in a deep anaesthetic plane prior to intravenous cannulation and airway instrumentation.[28] Some suggest waiting two minutes after loss of the eyelash reflex in children before the intravenous line is placed,[32] while others emphasize that a deep anaesthetic plane is a clinical diagnosis and not definable by a time interval.[31] Similarly, oropharyngeal airways should never be inserted while a patient is in a light plane of anaesthesia, even if airway obstruction occurs. The airway should rather be opened by a cautious jaw-thrust manoeuvre. Propofol induction and maintenance could cause less laryngospasm than sevoflurane.[11] Extubation should either occur at a deep level of anaesthesia or in a patient who is fully awake; both techniques have advantages and disadvantages.[28] Some advocate the "no touch" technique where the patient is left unstimulated with the airway device *in situ* until fully awake.[33] Others extubate while the lungs are fully inflated in order to reduce the adductor response of the larynx and to force the patient to exhale upon extubation, expelling secretions and reducing larynx irritation.[34]

Some studies have shown intravenous lignocaine (1 $mg.kg^{-1}$) to be effective in preventing post-extubation laryngospasm, while others were unable to demonstrate a benefit.[35,36] Glottic topicalization with 2% lignocaine at 4 $mg.kg^{-1}$ showed some benefit.[37] The potential danger of this practice is postoperative aspiration of blood or secretions if the airway is devoid of sensation. Intravenous $MgSO_4$ (15 $mg.kg^{-1}$) after intubation effectively decreased extubation laryngospasm, probably by increasing the anaesthetic depth and decreasing laryngeal muscle tone.[38] In cats, inhaling 5% CO_2 for 5 minutes prior to extubation reduced laryngospasm, probably because the drive to exhale the CO_2 overrides the laryngospasm reflex.[39]

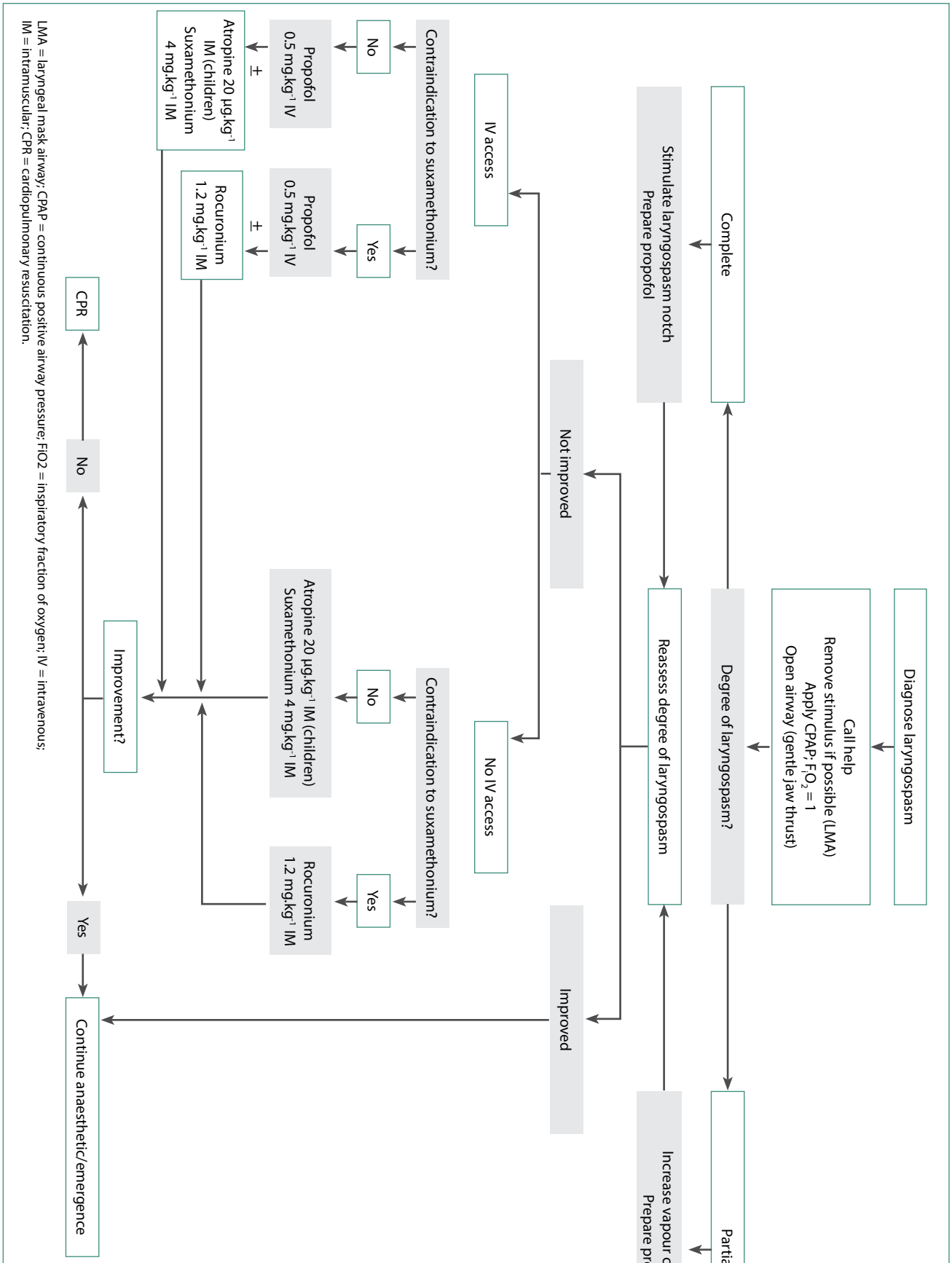


Figure 2: Personal treatment algorithm of the author:

LMA = laryngeal mask airway; CPAP = continuous positive airway pressure; FiO2 = inspiratory fraction of oxygen; IV = intravenous; IM = intramuscular; CPR = cardiopulmonary resuscitation.

CO_2 is of course not routinely available in theatre, and no human studies exist. The partial success of acupuncture[40] is another interesting observation, but most anaesthetists are not skilled acupuncturists.

Table IV: Possible strategies to prevent laryngospasm

Experienced anaesthetist
Anticholinergic premedication
Sedative premedication
Propofol induction (rather than thiopentone, ketamine or inhalants)
Deep plane of anesthesia prior to IV cannulation, airway instrumentation or surgical stimulation
Propofol maintenance (rather than sevoflurane)
Deep or fully awake extubation
Extubate following maximal inspiration
Intravenous lignocaine
Intravenous magnesium sulphate
Acupuncture
Inhaled CO_2 (cats)

IV = intravenous; CO_2 = carbon dioxide

Treatment (see Tables V and VI and Figure 2)

Most treatment guidelines concur that the first steps in the treatment of laryngospasm should include removing the stimulus, calling for help (to have extra hands to draw up drugs), applying a jaw thrust maneuver and 100% oxygen. Controversy surrounds some of the aspects of treatment. As part of removing the stimulus, some believe that the airway should be suctioned and examined for foreign bodies.[41] Personal experience has taught that this is firstly very difficult as jaw clenching often occurs at this point and inserting a suction device into the throat during a light plane of anaesthesia might stimulate further spasm of the larynx. Suctioning and inspection of the airway should probably only occur after deepening the anaesthetic plane or administering a muscle relaxant. A laryngeal mask should however be removed if possible if this was the initial trigger. This is also often only possible after pressure on the "laryngospasm notch" (see below) or pharmacological treatment of the spasm. Suctioning should only be done under vision and very cautiously following oropharyngeal surgery. Some authors list, as first line treatment of laryngospasm, the insertion of an oropharyngeal or nasopharyngeal airway.[28] This is contested by others because the patient is probably in a light plane of anaesthesia and inserting an object into the airway might worsen the spasm.[5] Also, an oropharyngeal airway should never be inserted after oropharyngeal surgery, as this might dislodge sutures or cause wound trauma. In these cases, laryngospasm should be treated without delay, as coughing and straining will increase venous pressure and cause bleeding. Deepening the anaesthetic is commonly accepted as a treatment option for laryngospasm, but some list the use of inhalational agents, even in complete obstruction.[28] It might be argued that inhalational agents will not reach the airway during complete laryngospasm[5], and deepening the plane of anaesthesia during complete laryngospasm is only possible with intravenous agents like propofol 0.25–0.8 $mg.kg^{-1}$,[17] which is successful in more than 75% of cases. Positive pressure ventilation as a treatment option is also controversial. Some regard this as imperative[28] while others question its potential for breaking a tight laryngospasm and regard the practice as dangerous due to the potential of stimulating stretch receptors if the patient accidently inhales, causing reflex apnoea.[5] Gastric insufflation with splinting of the diaphragm might also follow these high pressures.[42,43] Gentle manual assistance of breathing could be beneficial. Some mention gentle chest compressions as a treatment option,[44] but this study is criticised[41] for amongst others methodology and treatment delay while compressions are done. Short-acting opioids like alfentanil can be used, but will probably cause apnoea and less optimal intubating conditions than suxamethonium.[45] Guidelines concur that in the less than 25% of cases where propofol is not successful, suxamethonium should be used. Suggested intravenous dosages range from 0.1–3 $mg.kg^{-1}$. Propofol is initially preferred over suxamethonium because of the latter's possible interaction with non-depolarizing muscle relaxants, range of contra-indications and possibility of suxamethonium apnoea. Suxamethonium should however be administered before severe hypoxia ensues, as its administration under these conditions may result in bradycardia and cardiac arrest. It is recommended for the same reason, that suxamethonium be preceded by atropine 0.02 $mg.kg^{-1}$ in children.[28] The use of suxamethonium in extubation laryngospasm might follow shortly after the administration of neostigmine, in which case it should be remembered that pseudocholine esterase is also inhibited by neostigmine and the breakdown of suxamethonium might be prolonged.[46]

When laryngospasm occurs in the absence of intravenous access, the use of suxamethonium via the peripheral intramuscular (deltoid or quadriceps muscles) or intralingual route (4 $mg.kg^{-1}$ in both instances), will have an onset of action of 295 seconds and 265 seconds respectively. It is recommended that both submental and peripheral intramuscular injection sites be massaged post-injection as it could reduce the onset of action to 133 seconds.[47] The intraosseous route resembles the intravenous route in dosage and onset time. The intra-oral intralingual route, could cause bleeding and hematoma formation and may complicate airway management. Mask ventilation is also interrupted while injection occurs. The submental route is therefore advisable. These non-intravenous routes might have a slower onset of action than the intravenous route, but muscle relaxation occurs sooner in the larynx than in peripheral muscles, enabling airflow much quicker than the quoted onset times for non-intravenous suxamethonium.[48] The duration of action of intramuscular suxamethonium will however be prolonged to 15–30 minutes, compared to its six- to ten-minute duration via the intravenous route.[48] Most non-depolarizing muscle relaxants are not suitable for intramuscular use in laryngospasm, both due to their unacceptably slow onset of action via this route (mivacurium and atracurium > 10 minutes) and tissue irritation (atracurium).[49] Only rocuronium is deemed to have an acceptable onset of action via the intramuscular route,[49,50] keeping in mind that rocuronium burns intravenously and probably intramuscularly and could momentarily trigger further laryngospasm.[51] One study describes the use of intramuscular vecuronium (0.2–0.3 $mg.kg^{-1}$) in 12 patients.[52] This was not for laryngospasm but rather for routine intubation in conjunction with ketamine. Intubation was possible within 3–5 minutes. This is similar to the 4 minutes quoted for intramuscular rocuronium (1 $mg.kg^{-1}$ and 1.8 $mg.kg^{-1}$ in children < 1 year and > 1 year of age respectively).[49] Laryngospasm will probably cease even sooner. Intramuscular rocuronium is therefore an alternative to suxamethonium in patients with burns or other contraindications to suxamethonium in the absence of

intravenous access. The duration of action will however exceed 60 minutes.[50] The immediate reversal of both rocuronium and vecuronium is possible with sugammadex,[53] but intravenous access needs to be established. Although intramuscular administration was tolerated in rabbits,[54] no human studies exist and no data is available on the intramuscular route for sugammadex (personal communication with the manufacturing company). Sugammadex has also been implicated as a possible cause of laryngospasm (see above).

Five cases of post-extubation laryngospasm were reportedly treated with doxapram (1.5 $mg.kg^{-1}$ intravenously)[55] and 2 cases with nitroglycerin (4 $\mu g.kg^{-1}$ intravenously)[56]. The mechanism of action of doxapram is possibly the stimulation of respiratory drive but nitroglycerine is known to act on smooth muscle and this might not explain laryngeal muscle (skeletal muscle) relaxation.

Two non-pharmacological treatment options have been described. The first is well known but often applied incorrectly. Larson described a technique where pressure is applied to the "laryngospasm notch". This is often erroneously interpreted as pressure on the angle of the jaw or ramus of the mandible. The correct technique is the application of pressure with the middle fingers on a point bordered anteriorly by the ascending ramus of the mandible adjacent to the condyle, posterior by the mastoid process and superior by the base of skull. The operator presses firmly inwards and in a cephalad direction (in the direction of the styloid process, as cephalad as possible) with the middle fingers while performing a jaw thrust manoeuvre with the thumbs and index fingers to open the airway and maintain a thorough mask seal. The mechanism of glottic relaxation is not well understood, but probably results from pain-induced autonomic nervous systems effects.[45] The second technique is superior laryngeal nerve block to prevent post-extubation laryngospasm.[57,58]

Table V: Treatment options for laryngospasm

Removal of stimulus
Calling for help
Jaw thrust maneuver
Stimulation of the laryngospasm notch
100% Oxygen
Deepen the plane of anaesthesia (propofol, opioids, inhalational agents – partial laryngospasm)
Positive pressure ventilation
Gentle chest compressions
Suxamethonium (preceded by atropine in children) or rocuronium (see algorithm)
Other (doxapram, nitroglycerine, superior laryngeal nerve block)

Complications

Laryngospasm can be fatal if left untreated. Cardiac arrest, bradycardia, pulmonary aspiration and oxygen desaturation have been reported.[20] Post-obstructive negative pressure pulmonary edema is another concern. This occurs when patients generate a large negative pressure when inhaling against a closed glottis.[7] Complications following the treatment of laryngospasm is also possible. This includes the extensive list of side-effects of suxamethonium, hypotension of propofol and trauma caused by high pressure ventilation and intubation attempts with a closed glottis.

Laryngospasm is a treatable condition which can result in serious morbidity and mortality. Vigilance, good decision-making skills and thorough education, possibly through simulator training and algorithms, are vital for timeous diagnosis and treatment of laryngospasm.

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References:

1. Olsson GL, Hallen B. Laryngospasm during anaesthesia. A computer-aided incidence study in 136929 patients. Acta Anaesthesiol Scand, 1984;28:567-75.
2. Fink BR. The etiology and treatment of laryngeal spasm. Anesthesiology. 1956;17:569-77.
3. Burgoyne L, Anghelescu DL. Intervention steps for treating laryngospasm in pediatric patients. Paediatr Anaesth. 2008;18:297-302.
4. Black AE. Laryngospasm in pediatric practice. Pediatr Anesth. 2008;18:279.
5. Holzki J. Laryngospasm. Pediatr Anesth. 2008;18:1144-6.
6. Orliaguet AG, Gall O, Savoldelli GL, Couloigner V. Case scenario: perianesthetic management of laryngospasm in children. Anesthesiology. 2012;116:458-71.
7. Donlon JV, Doyle DJ, Feldman MA. Anaesthesia for eye, ear, nose and throat surgery. In: Miller RD, editor. Miller's Anesthesia. 6th ed. Philadelphia: Elsevier Churchill Livingstone;2005. p. 2527-55.
8. Hampson-Evans D, Morgan P, Farrar M. Pediatric laryngospasm. Pediatr Anesth. 2008;18:303-7.
9. Horita A, Dille JK. Observation on the action of thiopental on the laryngeal reflex. Anesthesiology. 1955;16:848-53.
10. Mcglone RG, Howes MC, Joshi M. The Lancaster experience of 2.0 to 2.5 mg/kg intramuscular ketamine for paediatric sedation: 501 cases and analysis. Emerg Med. 2004;21:290-5.
11. Oberer C, Von Ungern-Sternberg BS, Frei FJ, et al. Respiratory reflex responses of the larynx differ between sevoflurane and propofol in pediatric patients. Anesthesiology. 2005;103:1142-8.
12. Fisher D, Robinson S. Comparison of enflurane, halothane and isoflurane for diagnostic and therapeutic procedures in children with malignancies. Anesthesiology. 1985;63:647-50.

Table VI: Dosages and onset of action of different routes of muscle relaxants in laryngospasm

Agent	Route	Suggested dose	Onset of action
Suxamethonium	Intravenous	0.5 $mg.kg^{-1}$	30–60 s
	Interosseous	0.5 $mg.kg^{-1}$	30–60 s
	Intramuscular	4 $mg.kg^{-1}$	4 min
	Intralingual	4 $mg.kg^{-1}$	4 min
Rocuronium	Intravenous	1 $mg.kg^{-1}$	90 seconds
	Intramuscular	1.2 $mg.kg^{-1}$ 1.8 $mg.kg^{-1}$ in infants	4 min

s = seconds; min = minutes; mg = milligram; kg = kilogram

13. Coté CJ. Pediatric anesthesia. In: Miller RD, editor. Miller's Anesthesia. 6th ed. Philadelphia: Elsevier Churchill Livingstone; 2005. p. 2367-407.
14. McGuire B, Dalton AJ. Sugammadex, airway obstruction, and drifting across the ethical divide: a personal account. Anaesthesia. 2016;71:487-92.
15. Greenaway S, Shah S, Dancey M. Sugammadex and laryngospasm. Anaesthesia. 2017;72:405-16.
16. Visvanathan T, Kluger MT, Webb RK et al. Crisis management during anaesthesia: laryngospasm. Qual Saf Health Care. 2005;14:e3.
17. Batra YK, Ivanova M, Ali SS, et al. The efficacy of a subhypnotic dose of propofol in preventing laryngospasm following tonsillectomy and adenoidectomy in children. Pediatr Anesth. 2005;15:1094-7.
18. Nandwani N, Raphael JH, Langton JA. Effects of upper respiratory tract infection on upper airway reactivity. Br J Anaesth. 1997;78:352-5.
19. Murat I, Constant I, Maud'huy H. Perioperative anaesthetic morbidity in children: a database of 24.165 anaesthetics over a 30-month period. Pediatr Anesth. 2004;14:158-66.
20. Flick RP, Wilder RT, Pieper SF, Van Koeverde K, Ellison KM, Marienau MES, et al. Risk factors for laryngospasm in children during general anesthesia. Pediatr Anesth. 2008;18:289-96.
21. Shott SR, Cunningham MJ. Apnea and the elongated uvula. Int J Pediatr Otorhinolaryngol. 1992;24:183-9.
22. Aloe FS, Thorpy MJ. Sleep-related laryngospasm. Arq Neuropsiquiatr. 1995;53:46-52.
23. Erskine RJ, Murphy PJ, Langton JA. Sensitivity of upper airway reflexes in cigarette smokers: effect of abstinence. Br J Anaesth. 1994;73:298-302.
24. Loughlin CJ, Koufman JA, Averill DB, et al. Paroxysmal laryngospasm secondary to gastroesophageal reflux. Laryngoscope. 1996;106:1502-5.
25. Mortero RF, Orahovac Z, Tsueda K, et al. Severe laryngospasm at tracheal extubation in a patient with superior laryngeal nerve injury. Anesth Analg. 2001;92:271-2.
26. Bauman NM, Sandler AD, Schmidt C, et al. Reflex laryngospasm induced by stimulation of distal afferents. Laryngoscope. 1994;104:209-14.
27. Roy WL, Lerman J. Laryngospasm in paediatric anaesthesia. Can J Anaesth 1988;35:93-8.
28. Alalami AA, Ayoub CM, Baraka AS. Laryngospasm: review of different prevention and treatment modalities. Pediatr Anesth. 2008; 18:281-8.
29. Deckert J, Deckert L. Vocal cord dysfunction. Am Fam Physician. 2010;81(2):156-9.
30. Punj J, Darlong V, Pandey R. Paradoxical vocal cord motion - another cause to differentiate from laryngospasm. Pediatr Anesth. 2008;18:979.
31. Umesh G, Jasvinder K, Ramkumar V. Management of laryngospasm – our concerns and suggestions. Pediatr Anesth. 2008;18:978-9.
32. Schwartz D, Connelly NR, Gutta S, et al. Early intravenous cannulation in children during sevoflurane induction. Pediatr Anesth. 2004;14:820-4.
33. Lee KWT, Downes JJ. Pulmonary edema secondary to laryngospasm in children. Anesthesiology. 1983;59:347-9.
34. Landsman IS. Mechanism and treatment of laryngospasm. Int Anesthesiol Clin. 1997;3:67-73.
35. Baraka A. Intravenous lidocaine controls extubation laryngospasm in children. Anesth Analg. 1978;57:506-7.
36. Leicht P, Wisborg T, Chraemmer-Jorgensen B. Does intravenous lidocaine prevent laryngospasm after extubation in children? Anesth Analg. 1985;64:1193-6.
37. Koc C, Kocaman F, Aygenc E, et al. The use of perioperative lidocaine to prevent stridor and laryngospasm after tonsillectomy and adenoidectomy. Otolaryngol Head Neck Surg. 1998;118:880-2.
38. Gulhas N, Durmus N, Demirbileks S, et al. The use of magnesium to prevent laryngospasm after tonsillectomy and adenoidectomy: a preliminary study. Paediatr Anaesth. 2003;13:43-7.
39. Nishino T, Yonezawa T, Honda Y. Modification of laryngospasm in response to changes in P_aCO_2 and P_aO_2 in the cat. Anesthesiology. 1981;55:286-91.
40. Lee CK, Chien TJ, Hsu JC, et al. The effect of acupuncture on the incidence of postextubation laryngospasm in children. Anaesthesia. 1998;53:910-24.
41. Gavel G, Walker RWM. Laryngospasm in anaesthesia. Continuing Education in Anaesthesia, Critical Care and Pain. 2014;14(2):47-51.
42. Gal TJ. Airway management. In: Miller RD, editor. Miller's Anesthesia. 6th ed. Philadelphia: Elsevier Churchill Livingstone; 2005. p. 1617-52.
43. Chipas A, Ellis WE. Airway management. In: Nagelhout JJ, Plaus KL. Nurse Anesthesia. 4th ed. St Louis, MO:Saunders;2010. p. 441-64.
44. Al-Metwalli RR, Mowafi HA, Ismail SA. Gentle chest compression relieves extubation laryngospasm in children. J Anesth. 2010;24:854-7.
45. Mevorach DL. The management and treatment of recurrent postoperative laryngospasm. Anesth Anal. 1996;83:1110-1.
46. Fleming NW, Macres S, Antognini JF, Vengco J. Neuromuscular blocking action of suxamethonium after antagonism of vecuronium by edrophonium, pyridostigmine or neostigmine. Br J Anaesth. 1996;77:492-5.
47. Redden RJ, Miller M, Campbell RL. Submental administration of succinylcholine in children. Anesth Prog. 1990;37:296-300.
48. Warner DO. Intramuscular succinylcholine and laryngospasm. Anesthesiology. 2001;95:1039-40.
49. Horowitz BZ. Paralytic agents. In: Dart RC, editor. Medical Toxicology. 3rd ed. Philadelphia, PA: Lippincott Williams and Wilkens; 2004. p. 579-93.
50. Morgan GE, Mikhail MS, Murray JM, editors. Anesthesia for thoracic surgery. In: Clinical Anesthesiology. 4th ed. New York: McGraw-Hill; 2006. p. 585-613.
51. Szmuk P, Radulescu A, Ezri T, Geva D. Intramuscular Rocuronium. Anesthesiology. 1997;86:506.
52. Alpert CC, Bailey MK, Brahen NH, Dorman BH. J Cardiothorac Vasc Anesth. 1992;6(2):265.
53. Plaud B, Meretoja O, Hofmockel R, Raft J, Stoddart PA, van Kuijk JH, et al: Reversal of rocuronium induced neuromuscular blockade with sugammadex in pediatric and adult surgical patients. Anesthesiology. 2009;110:284-94.
54. European Medicines Agency. Assessment report for Bridion. London, UK. 2008.
55. Owen H. Postextubation laryngospasm abolished by doxapram. Anesthesia. 1982;37:1112-4.
56. Sibai AN, Yamout I. Nitroglycerin relieves laryngospasm. Acta Anaesthesiol Scand. 1999;43:1081-3.
57. Larson CP. Laryngospasm – best treatment. Anesthesiology. 1998;89:1293-4.
58. Monso A, Riudeubas J, Palanques F, et al. A new application for superior laryngeal nerve block: treatment or prevention of laryngospasm and stridor. Reg Anesth Pain Med. 1999;24:186-93.