Laryngospasm is an exaggeration of a protective reflex that prevents aspiration of foreign objects into the lower airway (eg, during swallowing). This results in complete or partial closure of the glottis, and impedance or total obstruction of airflow to the trachea and lungs. Often, the resulting hypoxia will by itself break a laryngospasm; however, if the spasm continues without relief, it can lead to pulmonary edema, cardiac dysrhythmias, cardiac arrest, and ultimately death. This evidence-based literature review explores the pathophysiology of laryngospasm and covers mechanical and pharmacologic prevention and treatment modalities in pediatric patients.

Keywords: Laryngospasm, pediatric, prevention, protective reflex, treatment.

Pediatric laryngospasm is a life-threatening event that results in complete or partial blockage of the airway. This blockage can lead to hypoxemia, negative-pressure pulmonary edema, pulmonary aspiration, and cardiac arrest. The treatment of laryngospasm has traditionally been succinylcholine, a short-acting, depolarizing neuromuscular blocking agent that relaxes muscle tension and breaks the laryngospasm. Succinylcholine, although very effective at treating laryngospasm, comes with potential serious side effects such as bradycardia and arrhythmias. In recent years, articles have been published that suggest different treatment modalities for pediatric laryngospasm, but providers have been slow to incorporate them into practice. Pharmacologic interventions such as the use of lidocaine, midazolam, or propofol have emerged as potentially useful treatments for breaking or preventing laryngospasm.

This literature review revisits principles in anesthesia regarding pathophysiology of laryngospasm, followed by methods for its prevention and treatment. The goal is to compile newer studies regarding pediatric laryngospasm and to present data and interventions that the anesthetists can incorporate in their practice, with the ultimate goal of improving patient outcomes.

Methods
This systematic review of the literature began with a search for articles pertinent to this topic. Multiple literary search engines were used to find these articles including: Academic Search Complete, CINAHL Complete, MEDLINE Complete, EBSCO host, Environment Complete, SPORTDiscus, Education Source, Business Source Complete, Communication & Mass Media Complete, SocINDEX, Military & Government Collection, PsycINFO, and PsycARTICLES. Article search criteria were limited to articles in English, published in the last 15 years, and with available full text. Certain articles published before 2002 were necessary to include for the literature review as they contained foundational knowledge pertinent to our topic. Searches were conducted using keywords, phrases, and specific subject headings, including pediatric, laryngospasm, treatment, break, pharmacology, prevention, incidence, propofol, lidocaine, magnesium, succinylcholine, extubation, maintenance, induction, risk factors, surgery, LMA [laryngeal mask airway], ETT [endotracheal tube], pathophysiology, airway, and maneuvers. The initial search yielded 3,275 results, 32 of which were included in this literature review once our inclusion criteria—pediatric focus, anesthesia related, full text form, peer-reviewed journals published in English—were applied. The evidence was evaluated using the method described by Melnyk and Fineout-Overholt. This review consists of 1 meta-analysis, 9 randomized controlled trials (RCTs), 1 nonrandomized controlled study, 7 prospective cohort studies, 7 retrospective cohort studies, 8 literature reviews, and 1 animal study.

Results
• Pathophysiology of Laryngospasm. Laryngospasm is an exaggeration of a protective reflex that prevents aspiration of foreign objects into the lower airway (eg, during swallowing). This results in complete or partial closure of the glottis, and impedance or total obstruction of airflow to the trachea and lungs. Often, the resulting hypoxia will by itself break a laryngospasm; however, if the spasm continues without relief it can lead to pulmonary edema, cardiac
The laryngospasm reflex is controlled by the extrinsic and intrinsic muscles of the larynx, and innervated by the internal branch of the superior laryngeal nerve, a branch of the vagus nerve. Abnormal excitation of this pathway occurs most commonly during lightened anesthesia (ie, stage 2) and thus poses the greatest threat during induction and emergence.

Furthermore, there are 3 mechanisms to laryngospasm—expiratory stridor, inspiratory stridor, and ball-valve obstruction. Expiratory stridor involves the intrinsic muscles of the larynx, and results in adduction of the vocal cords. Inspiratory stridor, also controlled by the intrinsic muscles, results from failure of the abductor muscles. Ball-valve obstruction is controlled by the extrinsic muscles, and involves closure of the false and true vocal cords, as well as collapse of soft tissue above the glottis.

- **Prevention of Pediatric Laryngospasm.** Agents used to prevent laryngospasm in pediatric patients include magnesium, lidocaine, and intermediate-acting muscle relaxants, such as rocuronium.

  - **Magnesium.** Magnesium is an intracellular cation and smooth muscle inhibitor. A study by Gulhas et al was performed on the efficacy of magnesium in the prevention of pediatric laryngospasm in patients undergoing adenotonsillectomy. This was a double-blind study in 40 patients between the ages of 3 and 12 years. Twenty participants in the magnesium group were given 15 mg/kg of magnesium sulfate 2 minutes after intubation. The other 20 patients were given 30 mL of normal saline. The results concluded there was no incidence of laryngospasm observed in the group that received magnesium, whereas the placebo group had a 25% rate (P < .05). The authors believe the mechanism of action of breaking laryngospasm is by deepening the anesthetic and enhancing muscle relaxation. This study had a small sample population and used intravenous (IV) lidocaine (1 mg/kg) on induction, which could be a confounding factor on magnesium’s prevention efficacy.

  Savran-Karadeniz et al conducted a similar study in 2016 that eliminated lidocaine from the anesthetic and used higher preventive magnesium doses (30 mg/kg). The surgical procedure studied was esophageal dilation in children between 2 and 12 years of age. The findings of this study showed that the incidence of laryngospasm in the group that received magnesium vs the control group was 10% and 33.3%, respectively (P = .057). This study’s findings corroborated the earlier study by Gulhas et al, but more studies are needed.

  - **Lidocaine.** Lidocaine has been a controversial and highly studied pharmacologic agent in the prevention of pediatric laryngospasm. Because of the uncertainty concerning the benefit of lidocaine, in 2014 Mihara et al conducted a systematic literature review and meta-analysis of the efficacy of lidocaine to prevent laryngospasm in children. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) was adhered to throughout the data collection process, and Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used to evaluate the quality of evidence for each study. The meta-analysis combined 9 different studies with a total of 787 patients. Studies examining both IV and topical lidocaine routes of administration were included. The results demonstrated a statistically significant reduction in the incidence of laryngospasm for both the IV and topical lidocaine routes. The authors postulated that the most efficacious time to administer IV lidocaine is within 5 minutes of tracheal extubation. Gharaei et al specifically compared IV vs topical lidocaine and found the difference in the prevention of pediatric laryngospasm to not be statistically significant.

  - **Intermediate-Acting Muscle Relaxants.** There has been minimal research done evaluating the use of intermediate-acting muscle relaxants in the prevention of pediatric laryngospasm. A study done by Martin-Flores et al evaluated the use of rocuronium on prevention of laryngospasm in cats. The researchers gave 8 cats anesthesia 4 separate times and used IV rocuronium at doses of 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, and 0.6 mg/kg. A videolaryngoscope was inserted through an LMA and recorded the laryngeal response to a sterile water spray. A response was recorded at baseline without rocuronium, and then after the rocuronium was given. The results showed a significant decrease in the completeness and duration of laryngeal responses with the rocuronium doses of 0.3 mg/kg and 0.6 mg/kg.

Although this study was done in cats and not pediatric patients, another study’s authors believed that long-acting muscle relaxants could facilitate better intubating conditions and lower laryngospasm rates following a failed laryngoscopy. A 2016 study by Spaeth et al focused on reducing serious airway events and airway cardiac arrests during pediatric anesthesia. The authors used 3 main quality indicators: nondepolarizing muscle relaxants in children younger than 2 years of age, for cases lasting less than 30 minutes, having succinylcholine and atropine out and available, and assessing ventilation after extubation by auscultation or end-tidal carbon dioxide. The finding of the study showed a 44% reduction in serious airway events and a 59% reduction in airway cardiac arrests. This study did not specifically look at the reduction of laryngospasm, but it did use long-acting muscle relaxants to decrease airway events such as laryngospasm.

- **Subhypnotic Dose of Propofol.** Propofol is known to inhibit airway reflexes and deepen anesthesia. Batra et al researched propofol’s ability to prevent pediatric laryngospasm. This RCT had 120 patients randomly assigned to receive either propofol, 0.5 mg/kg, before extubation or a control dose of the equivalent amount of saline. The presence of laryngospasm was evaluated by...
The most common physical technique is chest compression, also called the Larson Maneuver. Chest compression is beneficial for several reasons: (1) it is simple to perform, (2) it reduces the risk of hypotension compared with succinylcholine, and (3) it improves ventilation via the trachea. The Larson Maneuver is performed by first performing a jaw thrust to maximize mouth opening. The anesthetist then places upward pressure on the laryngospasm notch located slightly cephalad to the earlobe and between the mastoid process and mandibular condyle. Application of pressure here while simultaneously performing a jaw thrust may resolve a pediatric laryngospasm.

Other techniques include propofol and midazolam. Propofol inhibits airway reflexes and relaxes tissues in the upper airway. Advantages of propofol include rapid onset (30-45 seconds), rapid clearance, and avoidance of side effects such as bradycardia and myalgias associated with succinylcholine. However, the provider should be aware of side effects of propofol, including hypotension and transient apnea. Propofol is also useful in patients in whom succinylcholine is contraindicated (eg, burn victims, muscular dystrophies, cholinesterase deficiency).

Midazolam is also mentioned that midazolam decreases upper airway reflexes. Salah and Azzazi found that IV midazolam at 0.03 mg/kg effectively treated postextubation laryngospasm. In a group of 20 patients with laryngospasm, it was noted that 17 of the subjects responded favorably to midazolam. In similar fashion to propofol, midazolam decreases upper airway reflexes. Salah and Azzazi also mentioned that midazolam was effective in managing recurrent postoperative laryngospasm in anxious children, a condition referred to as hysterical stridor.

Succinylcholine. Succinylcholine has long been a preferred pharmacologic agent for treating laryngospasm because of its rapid onset and short duration of action. Intravenous succinylcholine is the gold standard in the treatment of pediatric laryngospasm, with a dose of 1 to 2 mg/kg. Succinylcholine is given along with atropine (0.02 mg/kg) to prevent bradycardia.

When IV access is unavailable, succinylcholine may be administered intramuscularly at a dose of 4 mg/kg. The disadvantage to this, however, is an onset time of 3 to 4 minutes for maximal twitch depression, although it has been suggested that relaxation of airway tissue occurs within 1 minute. Furthermore, at a dose of 4 mg/kg, succinylcholine may last upward of 20 minutes. Although sublingual and intraosseous routes are also acceptable, Walker and Sutton suggest that intramuscular succinylcholine is probably the most reliable agent to break laryngospasm when IV access is unavailable.

Physical Techniques to Treat Pediatric Laryngospasm: Different physical techniques can be attempted to break laryngospasm before pharmacologic intervention.

Positive-Pressure Ventilation. The most common physical method described by clinical providers is the immediate application of positive-pressure ventilation and administration of 100% oxygen. Gavel and Walker described that if a laryngospasm is suspected and there is soft-tissue compression of the larynx, application of positive pressure may relieve the obstruction. The initiation of positive-pressure ventilation could also relieve a supraglottic obstruction or partial laryngospasm.

Larson Maneuver. After positive-pressure ventilation has failed, the Larson maneuver is another technique that can be beneficial to help break a pediatric laryngospasm. Abelson explains that this maneuver, also called laryngospasm notch pressure, is the application of firm and inward pressure at the laryngospasm notch. This notch is located slightly cephalad to the eal and between the mastoid process (posterior) and mandibular condyle (anterior). Application of pressure here while simultaneously performing a jaw thrust may resolve a pediatric laryngospasm.

Discussion

Pediatric laryngospasm incidence has historically been 1.74%, but more recent data suggest that incidence is decreasing to 0.53%. Although the incidence may be
decreasing, there is still a need to further lower the incidence to achieve the best possible outcomes for pediatric patients undergoing anesthesia. Randomized controlled trials can help identify the most efficacious treatment options for laryngospasm, but algorithms help combine the RCTs’ findings into a tool that can help the practitioner make the best treatment decisions. There are a variety of algorithms for pediatric laryngospasm, but we want to build one that uses the most current RCTs and supporting evidence to provide the most up-to-date information on risk factors, prevention, and treatment options.

Many algorithms focus on treatment of laryngospasm, and not the prevention aspect. A focus on prevention is important because it can help eliminate the negative outcomes associated with pediatric laryngospasm such as oxygen desaturation, negative-pressure pulmonary edema, and death. There are many different pharmacologic therapies (eg, lidocaine, midazolam, propofol) that can be used to lower the incidence of laryngospasm. We created an algorithm (Figure) that has both the prevention and treatment options to provide the best outcomes for our pediatric patients. The rationale for this algorithm is explained here.

**Risk Factors.** Pediatric laryngospasm that is un-anticipated can be difficult to treat. Knowing and identifying risk factors for increased incidence of laryngospasm (see Figure) in the pediatric population must be of paramount importance. In our literature review, we identified several prominent risk factors that were prevalent in recent studies. Age of the pediatric patient is a major risk factor, with younger children more susceptible to laryngospasm. Another risk factor identified was obesity. Children at or above the 85th percentile of BMI and with a diagnosis of sleep-disordered breathing were found to have a significantly increased incidence of laryngospasm. Environmental tobacco smoke exposure and recent upper respiratory tract infections (within past 30 days) both were shown to increase rates of laryngospasm. Finally, the last risk factor identified was the type of procedure that the pediatric patient was undergoing. Several types of procedures with increased incidence of laryngospasm include appendectomy, otolaryngology (especially adenotonsillectomy), plastic surgery, hypospadias repair, and esophageal endoscopy.

**Prevention.** A study by Lee et al saw the adverse events and laryngospasm incidence increase with an increased number of attempts of pediatric laryngoscopy. This can vary greatly depending on provider experience and competency level. We recommend that intubation attempts be limited to the least possible number of attempts.

Several RCTs compared how ideal the intubating conditions were, with or without the use of muscle relaxants. The studies showed that intubating conditions were ideal, but more importantly there was no incidence of laryngospasm in either group. We did not recommend the use of muscle relaxants during induction to prevent laryngospasm in our algorithm (see Figure).

Magnesium was shown to be effective in 2 different RCTs. Magnesium is believed to help deepen the anesthetic and enhance muscle relaxation. Both studies used magnesium doses of 15 mg/kg and 30 mg/kg. We used the range of 15 to 30 mg/kg of magnesium before induction.

Intermediate-acting muscle relaxants for procedures have not been studied enough to include in a prevention algorithm.

**Figure.** Algorithm for Laryngospasm Treatment by Sequence in Pediatric Population

Abbreviation: IV, intravenous.
algorithm, but this drug class was shown to be effective in a randomized controlled trial in felines. There have been some attempts to use intermediate-acting neuromuscular blocking agents in different algorithms, but further studies are needed before we recommend them in our algorithm.

Lidocaine has been shown by a large meta-analysis to help prevent pediatric laryngospasm. This analysis included studies that used doses of 1.0 to 2.0 mg/kg of lidocaine intravenously and should be given within 5 minutes of tracheal extubation. Mihara et al also concluded that topically administered lidocaine lowers the incidence of laryngospasm, and the time of administration was either before intubation or during the airway device insertion. Mihara et al did not have a clear recommendation for the dose of topically applied lidocaine. (See Table.) We elected to use 1.0 to 2.0 mg/kg of IV lidocaine for our recommendation.

Propofol was shown to be highly effective in the prevention of pediatric laryngospasm. The study by Batra et al administered 0.5 mg/kg of propofol 60 seconds before extubation, which decreased the incidence of laryngospasm. This dose helps deepen the anesthetic and inhibit airway reflexes, preventing laryngospasms.

There was no clear evidence that extubating a patient who is awake vs under deep anesthesia had any advantage in preventing laryngospasm. There were no differences in laryngospasm rates in the studies that we included in our study. Therefore, we did not indicate an extubation preference for our prevention algorithm.

**Treatment.** The positive-pressure ventilation or continuous positive airway pressure (CPAP) with the administration of 100% oxygen is the most common and earliest method to treat laryngospasm. This treatment is recommended if there is a soft-tissue blockage that is compressing the larynx.

Larson maneuver is another quick early treatment option that has been used by providers. This technique uses the application of pressure slightly cephalad to the earlobe to facilitate patency of the upper airway. Larson maneuver should be used before pharmacologic agents, but a provider should not wait until desaturation of the patient to use other forms of treatment.

Gentle chest compressions is a treatment option for laryngospasm that has been studied in the literature. This treatment is thought to push air from the lungs against the vocal cords. The results of the study showed that gentle chest compressions could be an alternative and effective treatment compared with traditional methods to break laryngospasm. More studies are needed to determine the rate and force of the compressions, so we do not recommend this treatment in our algorithm yet.

Propofol has been studied and recommended as a preventive pharmacologic agent used for pediatric laryngospasm, but an RCT in 2014 found that it can be an effective treatment once a laryngospasm is present. This study used a subhypnotic dose of IV propofol (0.5 mg/kg) and found that it was effective in 75% of pediatric patients who had laryngospasm.

The same study that found that midazolam was also effective at treating postextubation laryngospasm. Benzodiazepines have been previously shown in the literature to decrease upper airway reflexes. Of 20 patients who were experiencing laryngospasm, 17 responded

<table>
<thead>
<tr>
<th>Source</th>
<th>Study design</th>
<th>Sample size</th>
<th>Results and conclusions</th>
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<tr>
<td>Oofuvong et al, 2014</td>
<td>Retrospective cohort study</td>
<td>N = 14,153 pediatric patients over 6-year period</td>
<td>• Laryngospasm incidence 0.53% for children ≤ 15 years</td>
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<td></td>
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<td>• URI increased the incidence of laryngospasm 1.7 times (95% CI = 0.78-3.7)</td>
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<td></td>
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<td>• LMA with assisted ventilation carried twice the risk of laryngospasm (95% CI = 1.2-3.3, ( P &lt; .001 ))</td>
</tr>
<tr>
<td>Drake-Brockman et al, 2017</td>
<td>RCT</td>
<td>LMA group: n = 85</td>
<td>• 3.82 times the incidence of laryngospasm in ETT vs LMA (95% CI = 1.13-12.96, ( P = .02 ))</td>
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<td></td>
<td></td>
<td>ETT group: n = 95</td>
<td>• Group that received IV magnesium had no laryngospasms, whereas group that received normal saline had a 25% incidence of laryngospasm (( P &lt; .05 ))</td>
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<td>Gulhas et al, 2003</td>
<td>Double-blind RCT</td>
<td>IV magnesium before induction: n = 20 Normal saline before induction: n = 20</td>
<td>• Demonstrated that IV or topical lidocaine is an effective medication in preventing pediatric laryngospasm</td>
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<td></td>
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<td>• Gentle chest compressions effectively treated 73.9% of laryngospasms that developed (( P = .0005 )), but the standard-practice group treated only 38.4% (( P &lt; .001 ))</td>
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<tr>
<td>Mihara et al, 2014</td>
<td>Meta-analysis</td>
<td>Combined 9 studies: N = 787</td>
<td>• Propofol group had a 6.6% incidence of laryngospasm vs a 20% incidence of laryngospasm in control group (( P &lt; .05 ))</td>
</tr>
<tr>
<td>Batra et al, 2005</td>
<td>RCT</td>
<td>Propofol group: n = 60 Control group: n = 60</td>
<td>• Propofol group had a 6.6% incidence of laryngospasm vs a 20% incidence of laryngospasm in control group (( P &lt; .05 ))</td>
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<td>Al-Metwalli et al, 2010</td>
<td>Nonrandomized controlled study</td>
<td>Gentle chest compression: n = 594 Standard-practice group: n = 632</td>
<td>• LMA with assisted ventilation carried twice the risk of laryngospasm (95% CI = 1.2-3.3, ( P &lt; .001 ))</td>
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Table. Conclusions From Most Pertinent Studies in Literature Review

Abbreviations: ETT, endotracheal tube; IV, intravenous; LMA, laryngeal mask airway; RCT, randomized controlled trial; URI, upper respiratory tract infection.
favorably to a midazolam dose of 0.03 mg/kg intravenously.4

Succinylcholine has long been the classic treatment of a patient having a laryngospasm.13 Because of the adverse side effects (eg, bradycardia, arrhythmias), it is usually the last option, but the most reliable pharmacologic agent to break a laryngospasm.2 The recommended dose of succinylcholine is 1.0 to 2.0 mg/kg intravenously or 4 mg/kg for the intramuscular route.5,17

Conclusion
Laryngospasm is still a potentially life-threatening event that occurs in the pediatric population. Although many studies have looked at the prevention and treatment of laryngospasm, researchers need to continue studying the issue until laryngospasm is eliminated. We believe that our algorithm combines evidence from the most recent studies to prevent and treat pediatric laryngospasm in the most effective manner. There has been a vast improvement in the incidence of pediatric laryngospasm and its treatment options with the advancements of surgical techniques, pharmacologic options, and a better understanding of the phenomenon. We believe that as more funding is obtained and studies are conducted on pediatric laryngospasm, the incidence will continue to decline.

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