Title: Updates in neonatal resuscitation: routine use of laryngeal masks as an alternative to face masks

Running title: Updates in neonatal resuscitation: laryngeal masks

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Conflicts of interest
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**Author Contributions**

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Abstract

Though positive-pressure ventilation (PPV) has traditionally been performed using a face mask in neonatal resuscitation, face mask ventilation has a high failure rate in delivering PPV due to mask leaks, airway obstruction, or gastric inflation. Further, face mask ventilation is compromised during chest compressions. Endotracheal intubation in neonates requires a high skill level, with a first-attempt success rate of <50%. Laryngeal masks can transfer positive pressure more effectively even during chest compressions resulting in lower failure rate of PPV compared to face masks in neonatal resuscitation. Further, inserting a laryngeal mask is easier and more accessible than endotracheal intubation, and there are no differences in the mortality rate between the laryngeal mask and endotracheal intubation in neonatal resuscitation. Therefore, in neonatal resuscitation, laryngeal masks are recommended in infants with gestational age >34 weeks and/or birth weight >2 kg in case of unsuccessful attempts at face mask ventilation (as a primary airway device) or endotracheal intubation (as a secondary airway device, alternative airway). In other words, laryngeal masks are recommended not only when endotracheal intubation fails but also when PPV cannot be achieved. Laryngeal masks are commonly used in anesthetized pediatric patients. However, laryngeal masks are not frequently used in neonatal resuscitation due to limited experience, a preference for endotracheal tubes, or a lack of awareness. Healthcare providers must be aware of the usefulness of laryngeal masks in depressed neonates requiring PPV or endotracheal intubation, which can promptly resuscitate these infants and improve the outcomes of them, resulting in decreased morbidity and mortality.

Key words: Laryngeal Masks; Endotracheal Intubation; Resuscitation; Infant, Newborn; Positive-Pressure Ventilation

Key message
In neonatal resuscitation,

- Laryngeal masks are recommended not only when endotracheal intubation fails but also when positive pressure ventilation cannot be achieved.
- Laryngeal masks can transfer positive pressure effectively even during chest compressions.
- Laryngeal masks are recommended in infants with gestational age >34 weeks and/or birth weight >2 kg.
- The main barriers to laryngeal mask usage in neonates are limited experience (81%), preference for endotracheal tubes (57%), and lack of awareness (56%).
- Second-generation laryngeal masks have a built-in esophageal drainage tube that prevents regurgitated fluid from spilling into the glottis, and an orogastric tube can be inserted within the esophageal drainage tube to protect against gastric inflation.
Introduction

Ventilation of the lung is the most important and effective step in neonatal resuscitation.\(^1\) Positive-pressure ventilation (PPV) is crucial for neonatal resuscitation, as cardiac failure occurs after respiratory failure in neonates. Therefore, ineffective ventilation can lead to cardiac failure, requiring intubation, chest compression, or epinephrine administration. PPV in neonates has traditionally been performed by face mask ventilation.\(^2\) However, there is a high risk of failure in delivering PPV due to a mask leak, airway obstruction, gastric inflation, or trigeminal nerve stimulation causing the trigemino-cardiac reflex.\(^3\) Furthermore, face mask ventilation is compromised during synchronized chest compressions due to increased mask leak, resulting in decreased tidal volume and minute ventilation.\(^4, 5\) Endotracheal intubation has a lower failure rate than face mask ventilation in delivering PPV without gastric inflation. Furthermore, it is effective during chest compressions. However, endotracheal intubation in neonates requires a substantial amount of simulated training and experience to acquire proper insertion skills, which need a longer time than the insertion of a laryngeal mask. Studies using laryngeal masks in anesthetized pediatric patients beyond infancy have shown that the laryngeal mask is better than face mask ventilation and is similar to endotracheal intubation.\(^6\) However, there is a lack of studies on the use of laryngeal masks in neonatal resuscitation, especially in preterm infants. Therefore, this review aimed to compare the effectiveness of laryngeal mask ventilation with that of face mask ventilation or endotracheal intubation for delivering PPV during neonatal resuscitation. Furthermore, we compared the different types of laryngeal masks used in neonatal resuscitation.

Introduction of laryngeal masks to initial PPV in neonatal resuscitation

Laryngeal masks have been used in neonatal resuscitation for several years. The American
Heart Association and American Academy of Pediatrics introduced laryngeal masks as an alternative to endotracheal tubes (as a secondary airway device) owing to the unsuccessful attempts at intubation according to the neonatal resuscitation program (NRP). They did not recommend the use of laryngeal masks as an alternative to face mask ventilation (as a primary airway device). Laryngeal masks are less invasive and relatively easy to insert without laryngoscopy. Therefore, laryngeal masks have been studied as an alternative to face mask ventilation during the initial stages of neonatal resuscitation. In 2020, the NRP recommended laryngeal masks as an alternative to face mask ventilation as the primary airway device or endotracheal intubation as the secondary airway device. Insertion of the laryngeal mask was included in Lesson 4 on ‘PPV’ (NRP Essentials) in the 8th edition of NRP,\(^7\) a change from Lesson 5 on ‘Endotracheal Intubation’ in the 7th edition of NRP.\(^8\) Recently, the International Liaison Committee on Resuscitation suggested the use of laryngeal masks in infants with gestational age >34 weeks and/or birth weight >2 kg in case of unsuccessful attempts at face mask ventilation or endotracheal intubation.

**Laryngeal masks versus face mask ventilation in neonatal resuscitation**

Six ventilation-corrective steps were performed to correct common problems associated with face mask ventilation during neonatal resuscitation. The six ventilation-corrective steps follow in this order: mask adjustment, reposition airway, suction mouth and nose, open mouth, pressure increase, airway alternative (MR. SOPA) which cause ineffective face mask ventilation in neonatal resuscitation.\(^9\) The laryngeal mask is less likely to leak and cause airway obstruction, and it can transfer positive pressure more effectively during chest compressions than a face mask. A systemic review by Qureshi et al. including five studies involving 661 infants, reported that the duration of PPV and resuscitation was shorter when a laryngeal mask
was used than when a face mask was used for ventilation.\(^{10}\) Additionally, the risk of PPV failure and the need for endotracheal intubation were lower when a laryngeal mask was used for ventilation than when a face mask was used for ventilation.\(^{10}\) A recent systemic review by Diggikar et al., including six studies involving 1853 infants with a gestational age of $\geq 34$ weeks and birth weight of $\geq 1.5$ kg or $\geq 2$ kg (946 in the laryngeal mask group vs. 907 in the face mask group) reported that the risk of PPV failure and the need for endotracheal intubation were lower in the laryngeal mask group than in the face mask group.\(^{11}\) Furthermore, time to recover spontaneous breathing and ventilation duration were shorter in the laryngeal mask group than in the face mask group, and both groups had similar mortality rates and moderate-to-severe hypoxic-ischemic encephalopathy.\(^{11}\) A systemic review of six randomized controlled trials that included 1823 infants with a gestational age of $\geq 34$ weeks reported that laryngeal masks are less likely to cause PPV failure needing endotracheal intubation than face masks.\(^{12}\) Furthermore, laryngeal masks decreased the duration to achieve a heart rate $>100$ beats per minute and the duration of PPV compared to face masks.\(^{12}\) A randomized controlled trial in Uganda involving 1154 infants with a gestational age of $\geq 34$ weeks or a birth weight of $\geq 2$ kg (563 in the laryngeal mask group vs. 591 in the face mask group) reported that the laryngeal masks were safe to be handled by midwives.\(^{13}\) However, the risks of death within seven days and moderate-to-severe hypoxic-ischemic encephalopathy were not decreased when a laryngeal mask was used for ventilation. Table 1 describes studies comparing laryngeal masks with face masks conducted on neonates within the last 10 years; older studies were excluded due to the rapid advancement of neonatal resuscitation in recent years.

**Laryngeal masks versus endotracheal intubation in neonatal resuscitation**

Endotracheal intubation requires proper insertion skills and laryngoscopy to confirm that the
endotracheal tube has passed through the vocal cords. However, insertion of a laryngeal mask is a relatively simple procedure. Endotracheal intubation requires specialists in neonatal resuscitation, such as skilled neonatologists; however, healthcare providers competent in managing the airway can insert a laryngeal mask. According to a study by the National Emergency Airway Registry for Neonates, the first-attempt success rate of endotracheal intubation was $<50\%$: 49% in the neonatal intensive care unit and 46% in the delivery room.\textsuperscript{14) Therefore, inserting a laryngeal mask may be preferred in emergencies such as neonatal resuscitation at birth.\textsuperscript{15) Additionally, some experts are concerned about delayed and inadequate resuscitation as a result of unsuccessful intubation attempts considering the neonatal intubation’s first-attempt success rate of $<50\%$ and the risk of severe desaturation.\textsuperscript{16) The mean time taken to insert a laryngeal mask was within 10 seconds in neonates with a gestational age of $\geq 35$ weeks or a birth weight of $\geq 2.5$ kg.\textsuperscript{17) However, according to a recent study reported in 2022, it took NRP providers 36 seconds to insert a laryngeal mask in a manikin, whereas it took them 32 seconds to insert an endotracheal tube in the same manikin.\textsuperscript{18) The NRP providers were less confident about inserting a laryngeal mask than endotracheal intubation. No significant differences in the time taken to insert the device and the success rate between the laryngeal mask and endotracheal intubation were reported in a systematic review of three studies involving 158 infants.\textsuperscript{10) Furthermore, the two groups had no significant differences in the mortality rate or rate of hypoxic-ischemic encephalopathy. Diggikar et al. found no significant differences in the rate of unsuccessful insertion, orofacial soft tissue injury, and Apgar scores at 5 min between the laryngeal mask and endotracheal intubation in infants with a gestational age of $\geq 34$ weeks or a birth weight of $\geq 1.5$ kg or 2 kg in a systemic review of three studies.\textsuperscript{11) Table 2 provides a description of studies comparing laryngeal masks and endotracheal intubation conducted on neonates within the last 10 years; older studies were
excluded due to the rapid advancement of neonatal resuscitation in recent years.

**Laryngeal masks during chest compressions in neonatal resuscitation**

Face mask ventilation is suboptimal for performing PPV in neonatal resuscitation, especially during chest compressions, which impedes adequate ventilation and delays the next steps of resuscitation, such as vascular access or epinephrine administration. Face mask ventilation during chest compressions is associated with decreased tidal volume and minute ventilation due to increased mask leakage compared to PPV alone. The evidence supporting the use of laryngeal masks during chest compressions in neonatal resuscitation is limited primarily due to a lack of experience. According to animal models comparing ventilation with a laryngeal mask and endotracheal tube during chest compressions, the mean airway pressure and expired tidal volume did not differ between lambs ventilated with a laryngeal mask and those ventilated with an endotracheal tube. The median time to achieve a return of spontaneous circulation was similar in the two groups, indicating that ventilation with a laryngeal mask was not inferior to ventilation with an endotracheal tube during chest compressions. In a manikin study comparing laryngeal mask and face mask ventilation during chest compressions, the peak inspiratory pressure was higher. The time taken to complete 30 cycles of three compressions and one ventilation was shorter in manikins ventilated with a laryngeal mask than in those ventilated with a face mask.

**Laryngeal masks in preterm infants in neonatal resuscitation**

The smallest laryngeal mask is size 1, which is designed to be suitable for infants weighing 2–5 kg. Therefore, there is insufficient evidence supporting the use of laryngeal masks in preterm infants. In a randomized controlled trial comparing laryngeal masks to face masks or
endotracheal intubation, the authors included infants with a birth weight of >1.5 kg. However, they did not provide information on the weight or number of infants enrolled with a birth weight of 1.5–2 kg. In another study comparing laryngeal mask to face mask, infants with a birth weight of <1.5 kg were excluded. However, this study did not provide information on the mean or range of birth weight or the number of enrolled infants with a birth weight of 1.5–2 kg who were included in the study. In a randomized controlled trial by Trevisanuto et al. comparing laryngeal mask to face mask, laryngeal masks were used in 22 infants with a birth weight of 1.5–2 kg. There have been some case reports on the use of a laryngeal mask in preterm infants to administer surfactant. Laryngeal masks have been used for surfactant administration in preterm infants, such as a gestational age of 30 weeks with a birth weight of 1.36 kg, a gestational age of 31 weeks with a birth weight of 1.335 kg, and a gestational age of 32 weeks with a birth weight of 1.53 kg. Trevisanuto et al. reported the use of a laryngeal mask in preterm infants with gestational age as low as 28 weeks and birth weight as low as 880 g. According to a pilot trial investigating the use of a laryngeal mask for surfactant administration in 13 preterm infants with a gestational age between 31 and 34 weeks and a birth weight between 1.67 kg and 2.82 kg, surfactant administration via laryngeal mask was found to be feasible and successful. Furthermore, laryngeal masks were successfully used to administer surfactant in preterm infants with a birth weight of ≥1.2 kg. However, the use of a laryngeal mask on a preterm infant with a birth weight of 670 g led to upper esophageal injury, which required extensive antibiotic treatment. Therefore, it is advisable to be careful while using laryngeal masks on preterm infants with a gestational age of ≤34 weeks or a birth weight of ≤2 kg, especially ≤1.5 kg.

Barriers to the use of laryngeal masks in neonatal resuscitation
According to a survey conducted in the United States on the use of laryngeal masks in neonates, only 12% of respondents had ever placed a laryngeal mask in a live newborn, even with low confidence in their ability to perform proper placement of the laryngeal mask. The most common barriers to the use of laryngeal masks in neonates were limited experience (81%), followed by insufficient training (59%), a preference for an endotracheal tube (57%), and lack of awareness (56%). According to a nationwide survey on the use of laryngeal masks in Brazil, most respondents recognized the usefulness of laryngeal masks in neonatal resuscitation, and over half of them (64%) were reported to know a laryngeal mask insertion. However, less than half (41%) were trained to use laryngeal masks. The most common barrier to the use of laryngeal masks in neonatal resuscitation was limited experience. In this survey, only 8% of the respondents reported having placed a laryngeal mask in the delivery room. Another barrier to the use of laryngeal masks during neonatal resuscitation in Brazil was their unavailability. According to another survey on the experience of laryngeal masks and endotracheal intubation in neonates in the United Kingdom, 47% had trained for the use of laryngeal masks, and only 7% had actually used it in a newborn infant. Even NRP providers did not perceive the insertion of a laryngeal mask as less challenging than endotracheal intubation. Additionally, they were not proficient in performing laryngeal mask insertion. This is another barrier to the use of laryngeal masks in neonatal resuscitation. Most studies on the use of laryngeal masks in neonatal resuscitation have excluded preterm infants with a gestational age <34 weeks or birth weight <2 kg, especially <1.5 kg. Therefore, there is insufficient evidence to support the use of laryngeal masks in this population, which possess a barrier to their adoption in neonatal resuscitation.

The evolution of various laryngeal masks over time
Second-generation laryngeal masks have a built-in esophageal drainage tube that prevents regurgitated fluid from spilling into the glottis (Figure 1). Additionally, an orogastric tube can be inserted for protection against gastric inflation. Furthermore, second-generation laryngeal masks have been developed to improve airway protection and increase airway seal pressure. The Laryngeal Mask airway ProSeal™ (LMA North America, San Diego, CA, USA) is a second-generation laryngeal mask designed for reusability. The Laryngeal Mask Airway Supreme™ (LMA® Supreme, Teleflex, Athlone, Ireland) is a second-generation laryngeal mask with a curved rigid airway tube. It is a disposable device currently available in two sizes (one and two) for pediatric use. All of these products are easily accessible domestically.

Conclusion

The NRP and International Liaison Committee on Resuscitation recommend the use of laryngeal masks as primary and secondary airway devices in neonates when attempts at face mask ventilation or endotracheal intubation are unsuccessful. However, laryngeal masks are not frequently used in neonatal resuscitation because of limited experience, a preference for endotracheal tubes, or a lack of awareness among healthcare providers. Unsuccessful intubation attempts can impede timely and proper resuscitation, resulting in the severe deterioration of neonates. The insertion of a laryngeal mask is a simple and easy procedure that can be preferred in emergencies for promptly resuscitating neonates. Healthcare providers must be aware of the usefulness of laryngeal masks in depressed neonates requiring PPV or endotracheal intubation, which can improve the outcomes of depressed neonates with decreased morbidity and mortality. There is insufficient evidence for the use of laryngeal masks in preterm infants, especially in those with a gestational age of ≤34 weeks or a birth weight of ≤2 kg, especially ≤1.5 kg.
References


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using the laryngeal mask airway. Anesthesiology. 1994;80(6):1248-53; discussion 27A.


Table 1. Studies conducted in the last 10 years comparing laryngeal masks with face masks in neonates

Table 2. Studies conducted in the last 10 years comparing laryngeal masks with endotracheal intubation in neonates
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<td>Infants with a GA of &gt;36 weeks with a BWt of &gt;2 kg requiring PPV at birth (Infants with meconium-stained amniotic fluid or congenital anomalies were excluded)</td>
<td>32 vs. 35</td>
<td>The duration of PPV was shorter, and the risk of device failure (requiring endotracheal intubation) was lower in LM group than in FM group (duration of PPV: 95.31 seconds vs. 180.86 seconds, device failure: 5/32 vs. 12/35). The mortality rate was not different.</td>
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<td>71 vs. 71</td>
<td>LMA supreme vs FM. The success rate of the devices (preventing endotracheal intubation) and Apgar score at 5 minutes was higher in the LMA group than in the FM group (success rate 91.5% vs. 78.9%).</td>
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<td>661 (5 RCTs)</td>
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<td>946 vs. 907 (6 RCTs)</td>
<td>The risk of device failure and endotracheal intubation were lower in LM group than in FM group. The time to recover spontaneous breathing and ventilation time was shorter in the LM group than in the FM group. Mortality rate and moderate-to-severe HIE were not different.</td>
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LM, laryngeal mask; FM, face mask; RCT, randomized controlled trial; GA, gestational age; BWt, birth weight; PPV, positive pressure ventilation; LMA, laryngeal mask airway; HIE, hypoxic-ischemic encephalopathy; SR, systematic review; RR, relative risk; CI, confidence interval

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316 Table 1. Studies conducted in the last 10 years comparing laryngeal masks with face masks in neonates

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<td>Yang et al.</td>
<td>2016</td>
<td>RCT</td>
<td>Infants with GA ≥34 weeks, or BWt ≥2 kg with a heart rate &lt; 60 beats per minute despite FM for 30 seconds (Infants with major malformations were excluded)</td>
<td>36 vs. 32</td>
<td>There were no significant differences in the first-attempt success rate (94.4% vs. 90.6%), insertion time (7.58±1.16 seconds vs. 7.89±1.52 seconds), Apgar score at 1 and 5 min, ventilation time, and successful resuscitation (86.1% vs 96.9%) between the LMA and ETI groups.</td>
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Figure legend

Figure 1. Second-generation laryngeal mask

The second-generation laryngeal mask incorporates a built-in esophageal drainage tube that prevents regurgitated fluid from spilling into the glottis. An orogastric tube can be inserted within the esophageal drainage tube to protect against gastric inflation. Further, the second-generation laryngeal mask improves airway protection and increases airway seal pressure.