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Neonatal Resuscitation Using the Laryngeal Mask Airway

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Background: For a newborn requiring positive-pressure ventilation (PPV), the American Heart Association recommends bag-and-mask ventilation, a challenging procedure for those inexperienced in neonatal resuscitation. The objective of this prospective study was to evaluate the laryngeal mask airway (LMA) as an alternative method of airway management in neonates requiring PPV at birth.

Methods: With the approval of the institutional ethics committee, consent was obtained from women in labor at a tertiary care-perinatal center. Inclusion criteria consisted of an expected birth weight of at least 2.5 kg, gestational age of at least 35 weeks, and resuscitation requiring PPV. Neonates meeting these criteria were resuscitated with PPV by means of the LMA. The ease of insertion, number of attempts required, time to establish effective ventilation, skin color, heart rate, respiratory effort, and Apgar scores were recorded.

Results: Attendance by the investigators at delivery was achieved in 93 cases, with 21 meeting the inclusion criteria. In all cases, the LMA was successfully inserted on the first attempt and provided a clinically patent airway. Twenty neonates were successfully resuscitated with the LMA to provide PPV, with no complications directly attributable to its use. One neonate required LMA removal and tracheal intubation

to facilitate administration of epinephrine; data from this case was removed from the study.

Conclusions: Providing PPV at birth *via* a size-1 LMA is effective and easily learned by personnel with expertise in neonatal resuscitation. The LMA should be further assessed as an alternative to bag-and-mask ventilation for this purpose. (Key words: Anesthesia, pediatric; neonatal. Equipment: laryngeal mask. Resuscitation.)

RESUSCITATION frequently is required during a neonate's adaptation to extrauterine life.¹ Of the approximately 3.5 million babies born annually in the United States, 6% require advanced life support in the delivery room; this increases to 80% for those whose birth weight is less than 1.5 kg.¹ The American Heart Association guidelines for neonatal resuscitation recommend that positive-pressure ventilation (PPV), when indicated, be administered by bag-and-mask.¹ This is a challenging procedure for those inexperienced in neonatal resuscitation.²

The laryngeal mask airway (LMA; Intavent International SA, Henley-on-Thames, England) developed in 1981 by Brain became available in 1988 for clinical use by anesthesiologists.³ Initially, the LMA was designed for use in adults; however, cadaveric studies in infants demonstrated that despite the anatomic differences between the adult and pediatric airways, the design of the LMA would not require modification for use in infants.³ The size-1 LMA is a smaller but identically shaped version of the adult model and is recommended for use in infants weighing 6.5 kg or less.⁴

To date, the LMA has been used in more than two million patients in the United Kingdom.⁵ In North America, interest in the LMA as an adjunct to airway management is increasing, and its use in anesthesia has recently been well described.⁶ Though limited, clinical experience with the LMA in children and infants is emerging, and several studies and case reports describing its use have been published.⁷⁻¹¹ In particular, Denny *et al.*¹² reported using the LMA to resuscitate a term newborn when ventilation of the lungs by bag-

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and-mask was inadequate and tracheal intubation proved impossible.

The objective of this prospective study was to evaluate the LMA as an alternative method of airway management, when used by investigators with expertise in neonatal airway management, for neonates requiring PPV during resuscitation.

Materials and Methods

After approval from the institutional ethics committee had been obtained, a prospective study of LMA use in neonatal resuscitation was conducted during September and October 1992 at the University of Alberta Hospitals. Inclusion criteria consisted of an expected birth weight of at least 2.5 kg, a gestational age of at least 35 weeks, and the need for resuscitation, including PPV. The need for PPV was determined by the presence of apnea or by heart rate (HR) less than 100 beats/min, consistent with guidelines for neonatal resuscitation published by the American Heart Association.¹ Written informed consent was obtained from women in labor with fetuses expected to fulfill the inclusion criteria for birth weight and gestational age. Neonates with a prenatal ultrasound diagnosis of congenital anomalies, a requirement for chest compression, suspected diaphragmatic hernia, or oropharyngeal pathologic lesions were excluded.

Before the study, the investigators who had expertise in neonatal resuscitation obtained further training from a pediatric anesthesiologist in the use of the LMA for airway management. This training involved using the LMA in 24 infants presenting for elective lower abdominal surgery over a 4-day period.

The study team attending the births consisted of one or more of the investigators and specially trained neonatal intensive care nurses familiar with the study protocol. The latter assisted in routine aspects of resuscitation and data collection. Initial management of the neonate was performed in the usual manner.^{1,2} If thick particulate meconium was observed in the pharynx of a depressed neonate, the pharynx was suctioned, and under direct laryngoscopy, the trachea was intubated to allow suctioning of meconium.¹³ All neonates had three surface electrodes applied to the chest, permitting a continuous electrocardiographic determination of heart rate.

If the neonate required PPV, the head was placed in the standard position for tracheal intubation, and a lubricated size-1 LMA, with the cuff fully deflated, was blindly inserted into the pharynx by one of the three

investigators. The LMA was advanced, with the aperture facing anteriorly, until resistance was encountered.⁴ The cuff was then inflated with 2–4 ml air to make a low-pressure seal around the larynx.⁴ The LMA was held in place and connected to a Jackson-Rees modification of an Ayres T-piece circuit, with an additional side port for pressure manometer readings. PPV was administered at an assisted rate of 40–60 breaths/min, and resuscitation continued in the usual manner.^{1,2} For neonates requiring chest compressions or in the presence of suspected diaphragmatic hernia, immediate tracheal intubation, rather than LMA use, was performed.

The number of attempts required to insert the LMA successfully and the time taken to establish effective ventilation (defined as adequate chest excursion, synchronous respiratory movements of the chest and reservoir bag, and bilateral air entry on auscultation of the axillae)^{1,2} were recorded. If the LMA could not be successfully inserted and effective ventilation established within 20 s, it was to be removed and one additional 20-s insertion attempt permitted. If two placement attempts failed, the LMA was to be removed and bag-and-mask ventilation instituted. If the investigators were unable to establish effective ventilation using the bag-and-mask, then tracheal intubation was to be performed.^{1,2} During initial lung inflation, with the successfully inserted LMA, the circuit pressure at which an audible leak occurred and the peak inspiratory pressure were recorded. No attempt was made to quantify the leak.

Skin color, HR, and respiratory effort were recorded before insertion of the LMA and 10, 20, 30, 60, and 90 s after insertion. An assessment of breath sounds also was recorded at the same intervals after LMA insertion. Apgar scores were recorded at 1, 5, and 10 min. The clinical response to resuscitation and airway patency was evaluated at 15–30-s intervals after initiation of PPV; if a positive response was demonstrated, administration of PPV with the LMA was continued as required. If the LMA initially provided a patent airway and if effective ventilation was established but later deteriorated during resuscitation, the LMA was removed, and bag-and-mask ventilation was instituted. When the HR was greater than 100 beats/min and spontaneous breathing was beginning, continuous positive airway pressure (CPAP) (5–10 cmH₂O) was provided. When the neonate was breathing spontaneously, CPAP was discontinued, and the LMA was removed once adequate, spontaneous respirations were observed.

Table 1. Demographic Characteristics

Characteristic	Value
Gestational age (weeks)	38.8 ± 2.1 (35–41)
Birthweight (g)	3,369 ± 655 (2,235–4,460)

Values are mean ± SD (range in parentheses); n = 21.

After resuscitation, neonates were transferred to the neonatal intensive care unit (NICU) or to the normal newborn nursery, at the discretion of the investigator. If a neonate required prolonged PPV (>10 min) or transport from the delivery room to the NICU while continuing to require PPV, the LMA was removed and tracheal intubation performed.

All data were collected and recorded in a standardized manner, entered into a computer system, and verified. Descriptive statistics and frequencies were determined on each variable at each time period. Comparisons among Apgar scores and among observations of skin color at different time intervals were performed using the Wilcoxon signed-rank test. Comparison among heart rates recorded at different time intervals were performed with a paired *t* test.

Results

One hundred thirty-two women were eligible for enrollment in the study; 2 chose not to provide consent, and 3 were unable to provide informed consent. The investigators attended the deliveries in 93 of the possible 127 cases. Failure to attend at delivery occurred for various reasons on 34 occasions, including precipitous and simultaneous delivery. Of the 93 deliveries attended, 21 neonates met the criteria for resuscitation with PPV and had a LMA inserted for airway management.

The demographic characteristics of the 21 neonates included in the study are presented in table 1. Increased perinatal risk was identified by maternal factors in 2 cases, fetal factors in 12 cases, and combined factors in 4 cases. Maternal risk factors included pregnancy-induced hypertension, oligohydramnios, intravenous drug abuse, and diabetes mellitus with a macrosomic fetus. Fetal risk factors included twin pregnancy, pathologic heart rate decelerations, passage of meconium, and intrauterine growth retardation.

Before insertion of the LMA, all 21 neonates had a HR of less than 110 beats/min (less than 100 beats/

min in 17 cases); 15 were apneic; and the remaining 6 displayed slow and irregular respiration. Two neonates required tracheal intubation for suctioning of meconium before any attempt at ventilation had been made; in both cases, after removal of the tracheal tube, PPV was required and the LMA was inserted. The principal investigator (SJP) was present at all 21 resuscitations and placed the LMA in 9 cases. Two coinvestigators placed the LMA in 9 and 3 cases, respectively.

One neonate had an initial HR of 20 beats/min, and the LMA was easily inserted to provide a patent airway and effective ventilation for 30 s. After the initial resuscitation, the HR remained at 20 beats/min, and the LMA was removed in favor of a tracheal tube to facilitate the administration of epinephrine and to ensure airway patency during the ensuing chest compressions. For these reasons, this case was removed from the study and excluded from analysis; the only data reported for this case are the demographic characteristics (table 1). This neonate died in the NICU, 6 h after birth.

In the remaining 20 neonates, the investigators found the LMA easy to insert with one attempt and thus able to provide a clinically patent airway for PPV, CPAP, and spontaneous breathing. Gastric distension was not observed during the resuscitation procedure. The time required for insertion, duration of LMA placement, circuit pressure at which an audible leak occurred, and peak inspiratory pressure obtained are displayed in table 2.

Before insertion of the LMA, all 20 neonates had bradycardia. In all cases, after 30 s of PPV the HR improved and the mean HR rapidly improved (fig. 1). Skin color rapidly improved after the initiation of PPV (fig. 2). Apgar scores measured at 1, 5, and 10 min were consistent with successful resuscitation^{1,2} (fig. 3).

Twenty neonates were successfully resuscitated with the LMA used to provide PPV. After resuscitation, 17 were transported to the normal care nursery, and the

Table 2. Laryngeal Mask Airway: Measured Values

Parameter	Value
Time for LMA insertion (s)	8.6 ± 1.4 (7–12)
Duration of PPV (s)	80 ± 61 (30–300)
Duration of CPAP (s)	55 ± 28 (15–120)
Circuit pressure, audible leak (cmH ₂ O)	22 ± 3 (17–29)
Circuit pressure, peak obtained (cmH ₂ O)	37 ± 3 (31–42)

Values are mean ± SD (range in parentheses); n = 20.

LMA = laryngeal mask airway; PPV = positive pressure ventilation; CPAP = continuous positive airway pressure.

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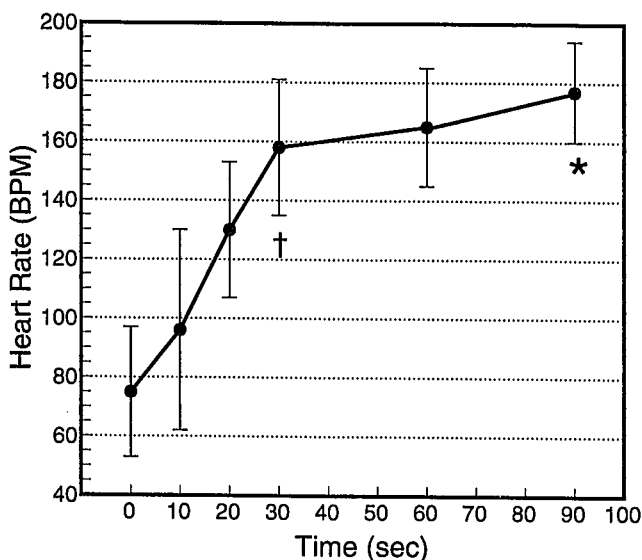


Fig. 1. Heart rate *versus* time before (time 0) and immediately after insertion of the laryngeal mask airway and initiation of positive-pressure ventilation. Values are means \pm SD; $n = 20$. *In two cases, the laryngeal mask airway was removed at 90 s; $n = 18$. †Significantly different from time 0 ($P < 0.001$, paired t test).

remaining 3 were admitted to the NICU for continued observation and care. Complete recovery, free of complications, occurred in 19 neonates. In one of the three neonates admitted to the NICU, a pneumothorax developed, requiring chest tube insertion 90 min after birth. The 20 neonates were examined during a follow-up visit 2 days after resuscitation, and no edema or bruising of the oropharynx was observed. No feeding difficulties were reported.

Discussion

This study demonstrates that a size-1 LMA can be used successfully in the resuscitation of neonates requiring PPV. A brief training period in the use of the LMA was adequate for the investigators to gain the skill required to use it effectively in neonates. The LMA was inserted successfully in all cases on the first attempt and thus provided a clinically patent airway for PPV, CPAP, and spontaneous breathing. All 20 neonates included in the study were successfully resuscitated with use of the LMA, and no complications were directly attributable to its use. Although use of the LMA to resuscitate a term newborn has been reported,¹² the size-1 LMA was not designed for this specific purpose. However, the in-

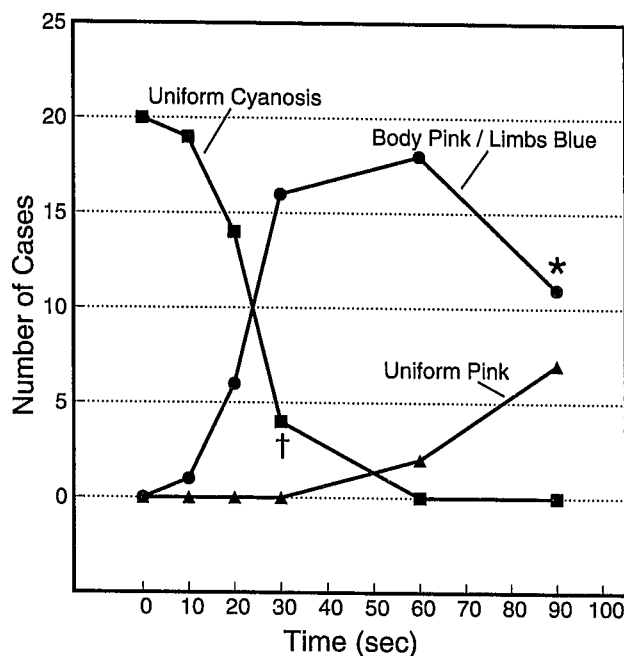


Fig. 2. Change in skin color *versus* time before (time 0) and immediately after insertion of the laryngeal mask airway and initiation of positive-pressure ventilation ($n = 20$). *In two cases, the laryngeal mask airway was removed at 90 s; $n = 18$. †Significantly different from time 0 ($P < 0.01$, Wilcoxon signed-rank test).

vestigators found it to be effective and easy to use in this setting.

Although the investigators had expertise in neonatal resuscitation, they had no experience in use of the LMA in neonates. The success rate observed in this study for

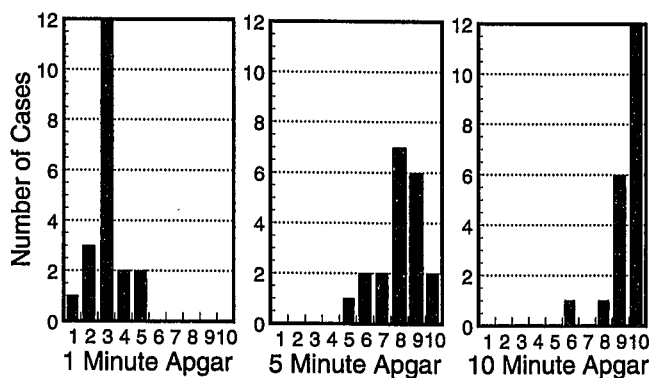


Fig. 3. Number of cases *versus* Apgar scores at 1, 5, and 10 min after clamping of the umbilical cord ($n = 20$). Significant differences were found at 1-5 ($P < 0.001$) and 5-10 ($P < 0.01$) min by the Wilcoxon signed-rank test.

LMA insertion and airway patency in neonates is consistent with the findings of Brodrick *et al.*¹⁴ and McCrerrick *et al.*,¹⁵ who demonstrated success rates of 98% and 94%, respectively, for clinical airway patency when the LMA was used in adults by anesthesiologists with no prior experience.

Despite the anatomic differences between the adult and neonatal airways, the investigators inserted the LMA without difficulty, in the manner described by Brain,⁴ in the neonates in this study. They did not need to use additional clinical maneuvers with the LMA to overcome the positioning problems described by others during its insertion in infants and children.^{9,16} The size-1 LMA provided a clinically patent airway for PPV, CPAP, and spontaneous breathing in all cases. The investigators' experience in neonates parallels that of others who have demonstrated a clinically patent airway in 96–100% of pediatric patients after LMA insertion.^{7–9,11}

Mizushima *et al.*⁷ assessed the position of the size-1 LMA and airway patency in 50 infants and found that in 24% of the infants, a delayed airway obstruction developed. They concluded that the LMA tended to become displaced in infants. In 50% of these cases, however, patient movement and consequent dislodgment of the LMA were cited as the reason airway obstruction developed.⁷ In the current study, airway obstruction did not develop after establishment of initial airway patency. This may be because the investigators applied continuous manual fixation of the LMA and because its use as required for resuscitation was brief.

The design of the LMA prevents the distal end from entering the esophagus while it sits in the hypopharynx over the laryngeal inlet.^{4,5} When the cuff is inflated, a gas-tight seal (as great as 20 cmH₂O pressure) exists between the larynx and the LMA.^{4,5} Goudsouzian *et al.*¹⁰ found an audible leak with a size-1 LMA at a mean pressure of 17 cmH₂O (range 8–28 cmH₂O) during controlled ventilation of the lungs. In the current study, a higher mean pressure could be generated before an audible leak occurred (table 2). This may be because the investigators held the LMA in place and applied continuous forward pressure on the LMA, which would not be possible if it were secured with tape.

To establish effective ventilation after birth, the neonate must generate an opening pressure of 20–40 cmH₂O.^{2,17} Alternatively, when PPV is used, this positive airway pressure must be generated during inspiration, before movement of air into a newborn's lung. The pressure of subsequent breaths ranges from 15–

20 cmH₂O in neonates with normal lungs.² Consequently, the authors initially were concerned that the pressures that could be generated by the circuit before leakage at the cuff–laryngeal seal would not be great enough to exceed the neonates' opening pressure. However, each neonate's lungs were successfully ventilated, and the opening pressure was exceeded, even though the pressures achieved in most cases were lower than the theoretically required opening pressure (table 2). Because the opening pressure required is higher in a premature newborn or one with lung disease, both the pressure generated before an audible leak occurs at the LMA and the peak inspiratory pressure may not be adequate to ventilate these neonates with decreased lung compliance. Gastric inflation, a well-recognized occurrence with bag-and-mask PPV,^{1,2} was not observed during LMA use in this study.

The investigators attended 93 deliveries, and in 21 (23%), the newborn required resuscitation with PPV. This study was conducted in a tertiary care–perinatal center, and 18 of the 21 neonates were at increased perinatal risk from fetal, maternal, or combined factors. The 34 deliveries not attended by the investigators were managed by nursing staff in a standard fashion and had a resuscitation rate of 21% (7 of 34).

The lowest weight at which a size-1 LMA can be used is not known. One neonate in this study had a gestational age of 35 weeks, and at delivery the estimated weight was 2.5 kg. However, after an uneventful resuscitation using the LMA, the birth weight was recorded at 2.235 kg. The authors are unaware of any reports of use of the LMA in a smaller neonate.

The newborn in whom a pneumothorax developed had a birth complicated by intrauterine fetal distress and after delivery had an unremarkable resuscitation. During PPV, an audible leak occurred at 18 cmH₂O pressure, and a peak inspiratory pressure of 34 cmH₂O was obtained during resuscitation. The clinical evaluation during PPV, CPAP, and spontaneous breathing was consistent with a patent airway, and the response to resuscitation was satisfactory. After removal of the LMA, the condition of this newborn was initially stable, but persistent respiratory distress developed, and the newborn was admitted to the NICU for observation. Ninety minutes later, tracheal intubation and chest tube insertion were required for relief of a pneumothorax. The trachea was extubated the following day and the chest tube subsequently removed. The newborn was released from NICU after 3 days and discharged home 2 days later, with no sequela from the pneumothorax.

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Although it is possible that the pneumothorax was associated with our resuscitation efforts, the overall incidence of spontaneous pneumothorax in newborns is 1–2%.^{13,18} This incidence is increased in cases of fetal distress, meconium aspiration, and difficult delivery, which occurred frequently in our study population.^{13,18}

The neonate who died had shown signs of severe fetal distress before birth, with a persistent fixed bradycardia of less than 60 beats/min. Delivery was by emergency cesarean section. Despite immediate aggressive resuscitation in the operating room and ongoing treatment in the NICU, this neonate did not recover and died 6 h after birth. Analysis of blood cultures subsequently demonstrated Group B streptococcal septicemia.

The investigators suggest caution in the use of the LMA in neonates beyond the population studied, which did not include neonates who required closed-chest compressions or neonates who were suffering from congenital anomalies, oropharyngeal pathology, diaphragmatic hernia, or prematurity. In addition, this pilot study was carried out by investigators who possessed expertise in neonatal airway management; the results may not be applicable for others unfamiliar in this area. A prospective randomized application of this technique is currently underway to determine if a broader application of the technique is justified.

The authors conclude that the use of a size-1 LMA in neonatal resuscitation is an effective and easily learned method of airway management when used by personnel with expertise in neonatal resuscitation. It remains to be seen if this is a technique that can easily be adopted by other personnel, both medical and nursing, who routinely resuscitate newborns in the delivery room. The LMA should be assessed as an alternative to bag-and-mask ventilation for neonatal resuscitation.

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