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ARTICLE

Airway Obstruction During Mask Ventilation of Very Low Birth Weight Infants During Neonatal Resuscitation

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What's Known on This Subject

There is little information available regarding the frequency of airway obstruction during bag-and-mask ventilation of VLBW infants during resuscitation at birth. The use of the colorimetric CO_2 detector during bag-and-mask ventilation in the delivery room has been described.

What This Study Adds

This study has shown that initial attempts to provide ventilation by using bag-and-mask ventilation frequently result in airway obstruction in the VLBW infant and that a colorimetric CO_2 detector allows the team to recognize these events and attempt to correct them.

ABSTRACT

OBJECTIVES. The delivery of adequate but not excessive ventilation remains one of the most common problems encountered during neonatal resuscitation, especially in the very low birth weight infant. Our observations suggest that airway obstruction is a common occurrence after delivery of such infants, and we use colorimetric carbon dioxide detectors during bag-and-mask resuscitation to assist in determining whether the airway was patent. We reviewed our experience to determine the frequency of the occurrence of recognizable airway obstruction during resuscitation of very low birth weight infants.

METHODS AND PATIENTS. The previous prospective trial randomly assigned preterm infants <32 weeks' gestation to resuscitation with either room air or 100% oxygen using pulse oximetry. Colorimetric carbon dioxide detectors were used to assist with bag-and-mask ventilation and to confirm intubation. From the video recordings, the number of positive pressure breaths without a color change in the detector until the breaths were associated with an unequivocal color change was counted as obstructed breaths. From the analog tracings, the number of breaths that had a peak pressure plateau of ≥0.2 second and were not associated with a color change was recorded as the number of obstructed breaths.

RESULTS. None of the studied infants required cardiopulmonary resuscitation or received epinephrine, and all were judged to have an effective circulation during resuscitation. Six of the 24 infants enrolled in the trial received only continuous positive airway pressure. The remaining 18 infants received a median of 14 obstructed breaths (range: 4–37 breaths) delivered over a mean and median interval of 56.7 and 45.0 seconds, respectively (range: 10.0–220.0 seconds). A subgroup of 11 infants was analyzed using airway-pressure data. The target peak inspiratory pressure was 30 cm H_2O. Ten of these 11 infants had obstructed breaths as defined by no change in the PediCap despite reaching the target pressure for ≥0.2 second.

CONCLUSION. Airway obstruction occurs in the majority of the very low birth weight infants who receive ventilation with a face mask during resuscitation and the use of a colorimetric detector can facilitate its recognition and management. *Pediatrics* 2009;123:865–869

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Key Words
colorimetric carbon dioxide detector, bag and mask, airway obstruction, resuscitation, VLBW, very low birth weight

Abbreviations
VLBW—very low birth weight
UCSD—University of California San Diego
CPAP—continuous positive airway pressure
ELBW—extremely low birth weight

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AT THE TIME of birth, a substantial proportion of very low birth weight (VLBW) infants require intervention to support their ability to transition from intrauterine life. Most commonly, this takes the form of positive pressure ventilation using any one of a number of devices, including self-inflating bags, anesthetic-type bags, or t-piece resuscitators to assist in the absorption of lung fluid and the establishment of an adequate lung volume with a functional residual capacity. The ideal result of the first positive pressure breath is to stimulate the infant to make a response by either initiating a spontaneous breath or making a rejection response against the inspiratory pressure, which will assist in the process of lung expansion and establishment of a functional residual capacity.[1,2] One of the most common areas of concern during resuscitation is the delivery of adequate but not excessive bag-and-mask ventilation.[3] Infants who do not initiate spontaneous inspiratory efforts or who do not respond to positive pressure breaths frequently have continued bradycardia and hypoxia, likely secondary to poorly inflated lungs.

The difficulties experienced with positive pressure ventilation of the nonintubated premature infant may be secondary to a number of factors including inexperienced personnel; inappropriate equipment, such as poorly fitting masks resulting in a leak; or the presence of airway obstruction at birth. We have reported previously that we use colorimetric carbon dioxide detectors during bag-and-mask resuscitation to assist in determining whether the airway is patent.[4] Our initial observations using this device described its use during intubation in the NICU as a part of a prospective trial of premedication.[5]

We have made the use of such a colorimetric detector mandatory during bag-and-mask ventilation in our NICU and in the delivery room during neonatal resuscitation. Through our review of video recordings, we have observed that airway obstruction is a relatively common phenomenon during initial bag-and-mask resuscitation, especially of the very preterm infant. Prolonged unrecognized airway obstruction could easily lead to further, more aggressive, and hazardous procedures, such as increased pressures and/or compressions if not rapidly recognized and relieved. In addition we believe that efforts should be made to stabilize the very preterm infant before attempts at intubation, which can cause further deterioration, especially in the presence of existing bradycardia and/or desaturation.[6,7] We have now reviewed our experience from a subsequent prospective randomized trial, which included the video recording of the resuscitation using our previously defined methodology.[8,9]

METHODS

Infants reviewed were born at the University of California San Diego (UCSD) Medical Center, a regional NICU with 40 beds and a high-risk perinatal service admitting ~110 VLBW infants per year. Each delivery was attended by a team consisting of a pediatric resident, neonatal fellow, neonatal nurse, and respiratory therapist. An attending neonatologist was present as well at most of the deliveries. Colorimetric carbon dioxide detectors (Pedicap [Nellcor Puritan Bennett, Pleasanton, CA]) were used to assist with bag-and-mask ventilation and to confirm intubation. A t-piece resuscitator (Neopuff [Fisher & Paykel, Auckland, New Zealand]) was used as the primary device for the provision of positive pressure ventilation and/or continuous positive airway pressure (CPAP), and flow-inflating bags are occasionally used when infants require high pressures, but none were used during the periods of resuscitation analyzed in this study.

We reviewed the video recordings from infants enrolled in our center from our previous trial comparing room air and oxygen for resuscitation of the extremely low birth weight (ELBW) infant. This previous prospective trial randomly assigned preterm infants <32 weeks' gestation to resuscitation with either room air or 100% oxygen using pulse oximetry and was conducted in 2 centers. Oxygen was provided to the room-air infants when preassigned oxygen saturation targets were not met at various time points.[9] For all of the infants, a pulse oximeter was applied within the first 30 seconds of life. All of the saturations obtained and recorded were from a preductal site, usually the right wrist. The base unit was turned on, and the probe was applied to the infant, followed by attachment of the probe to the base unit. This methodology follows the manufacturer's guidelines to maximally decrease time to a reliable signal, confirmed by O'Donnell et al.[10] Radical oximeters (Masimo, Irvine, CA) were used along with HiFi sensors (Masimo, Irvine, CA), which automatically set the oximeter to maximal sensitivity and 2-second averaging. Resuscitations were video recorded using our previously described methodology.[8] At the UCSD site, a purpose-built computerized, data acquisition system continuously collected delivered fraction of inspired oxygen using the output of an inline polarographic oxygen analyzer, airway pressure from the t-piece, time-linked video, and pulse oximeter outputs, including pulse rate and pulse oxygen saturation.[5]

Colorimetric carbon dioxide detectors are devices that change color in the presence of exhaled carbon dioxide and are currently recommended to rapidly recognize the success or failure of endotracheal intubation. We reviewed the video recordings to determine at what point the color of the carbon dioxide detector, placed between the t-piece and the face mask, changed from a constant purple to an alternating purple and yellow color. The number of positive pressure breaths without a color change in the detector was counted until a breath was associated with an unequivocal color change. The number of breaths without a color change was recorded as the number of obstructed breaths. We noted that the airway did not always remain patent after this first opening event, but we did not analyze subsequent airway obstructions in this analysis.

For infants who were connected to the full analog recording system (not always available during the study), we performed the same review using the analog database. The breaths were analyzed in a similar manner, and the airway pressure recorded during each breath was reviewed and the actual delivered pressure noted. Because our initial settings for the t-piece in the delivery area were 30 cm H_2O peak inspiratory pressure and 5 cm H_2O end expiratory pressure, only breaths that reached 30 cm H_2O for >0.2 second and were not associated with any PediCap color change were counted as obstructed (Fig 1).

Patients

All of the infants reviewed were ≤32 weeks' gestational age at birth and enrolled in our prospective trial. Parental consent was obtained before delivery, which included consent for the video recording and data collection. This study received the approval of the UCSD Medical Center Human Subjects Committee.

TABLE 1 Study Infant Demographics

Variable	All Infants ($N = 24$)	CPAP Only ($N = 6$)	Positive Pressure Ventilation Received ($N = 18$)
Gestation, mean (range), wk + d	27 (24–31)	28 (24 to 30)	27 (25–31)
Body weight, mean (SD), g	955 (353)	1121 (319)	886 (355)
1-min Apgar score, median (25th, 75th)	5 (4, 7)	8 (7, 8)	4 (3, 6)
5-min Apgar score, median (25th, 75th)	8 (8, 9)	8 (8, 9)	8 (7, 9)
Intubated in delivery room	17	4	13

Statistics

We manually counted the obstructed breaths and recorded the number of breaths without observable color change for each patient. We performed descriptive statistics using SigmaStat 3.0.1A (SYSTAT Software Inc, San Jose, CA).

RESULTS

There were 24 infants delivered at the UCSD Medical Center whose resuscitations were reviewed from the prospective trial. The demographics for these infants are shown in Table 1. None of the studied infants required cardiopulmonary resuscitation or received epinephrine, and all were judged to have an effective circulation during resuscitation.

We noted that 6 of the 24 infants had a patent airway, as demonstrated by a color change on the carbon dioxide detector with the application of CPAP only, and 4 of these later went on to be intubated. The remaining 18 infants received a median of 14 consecutive obstructed breaths (range: 4–37 breaths) delivered over a mean and median interval of 56.7 seconds and 45.0 seconds, respectively (range: 10.0–220.0 seconds). If the 220.0-second outlier is eliminated, the mean and median become 45.7 and 35.0 seconds, respectively.

Thirteen of the 18 infants who received positive pressure ventilation at birth were intubated in the delivery room. All of the infants were admitted to the Infant Special Care Center. A subgroup of 11 infants was analyzed using the available analog pressure data. We did not have the analog pressure data for the other 7 infants, because the recording apparatus either did not function properly or there were multiple births, and although we had cameras for each bed, we had only 1 acquisition system. The target peak inspiratory pressure at the time of the effective breath was 30 cm H_2O. Ten of these 11 infants had obstructed breaths as defined by no change in the Pedicap despite reaching the target pressure for $\geq$0.2 second. One infant was given 19 breaths before a color change was noted, but none of them reached the target pressure. For this reason, it was not certain whether his airway was obstructed or whether the leak limited gas exchange with the Pedicap (Fig 1, tracing 2). Interventions to overcome the obstruction occurred at a median of 4 breaths. The first interventions included repositioning of the head ($n = 10$), checking the mask seal ($n = 5$), a new operator ($n = 2$), and increasing the pressure ($n = 1$).

The intervention that was most likely to be successful, whether a primary intervention or a follow-up, was repositioning of the head. The infant who was an outlier and did not convert for 220 seconds had his seal checked/changed several times, but no attempt was made to reposition the head. It seems from this example that repositioning of the head can be a critical intervention.

DISCUSSION

We have demonstrated previously that the use of a colorimetric carbon dioxide detector is useful in determining whether there is a patent airway during the delivery of positive pressure breaths for infants in the NICU. The current observations add to our previous experience and demonstrate that failure of a color change is very frequent after delivery of a VLBW infant and is a significant factor in the failure to deliver adequate positive pressure breaths immediately after delivery. Our methodology for the majority of infants who received positive pressure ventilation included the use of proximal airway-pressure tracings during resuscitation. It could be argued that our observations relative to the lack of color change on the colorimetric carbon dioxide detector could be secondary to a large airway leak. However, we used a t-piece for all of the analyzed breaths during our resuscitations, and the inspiratory time was always >0.2 second at the peak pressure except in 1 infant (Fig 1, tracing 2). Our ability to deliver a pressure of 30 cm H_2O would have resulted in the delivery of a significant volume of gas to the infant irrespective of an airway leak if the airway was open. We have subsequently determined that the minimal volume of 5% carbon dioxide that will produce an unequivocal color change is 1 mL with currently available detectors.[11] Assuming the delivery of 30 cm H_2O and a lung compliance as low as 0.2 mL/cm H_2O, we would deliver a volume of 6 mL to the lung whether a leak was present or not if the peak pressure was reached and held for 0.2 second. Another potential reason for failure to obtain color change is purely a lack of compliance in a fluid-filled lung, which requires additional opening pressure, and, on occasion, such pressure increases resulted in the delivery of tidal breaths (Fig 1, tracing 1).

Our data show that the use of a colorimetric detector provides the resuscitation team with a visible signal that can provide an indication of airway patency. Previous methods of determining airway patency included evaluating chest rise and evaluating the changes in heart rate and pulse oximetry. From our experience, even with a very experienced team, the pulse oximeter is not functional within the first minute of life, which was the time frame for almost all of our observations. Even minimal chest rise in the very preterm infant may be indicative of an excessive volume, and it is difficult during a resuscitation to determine the actual chest motion. We now have

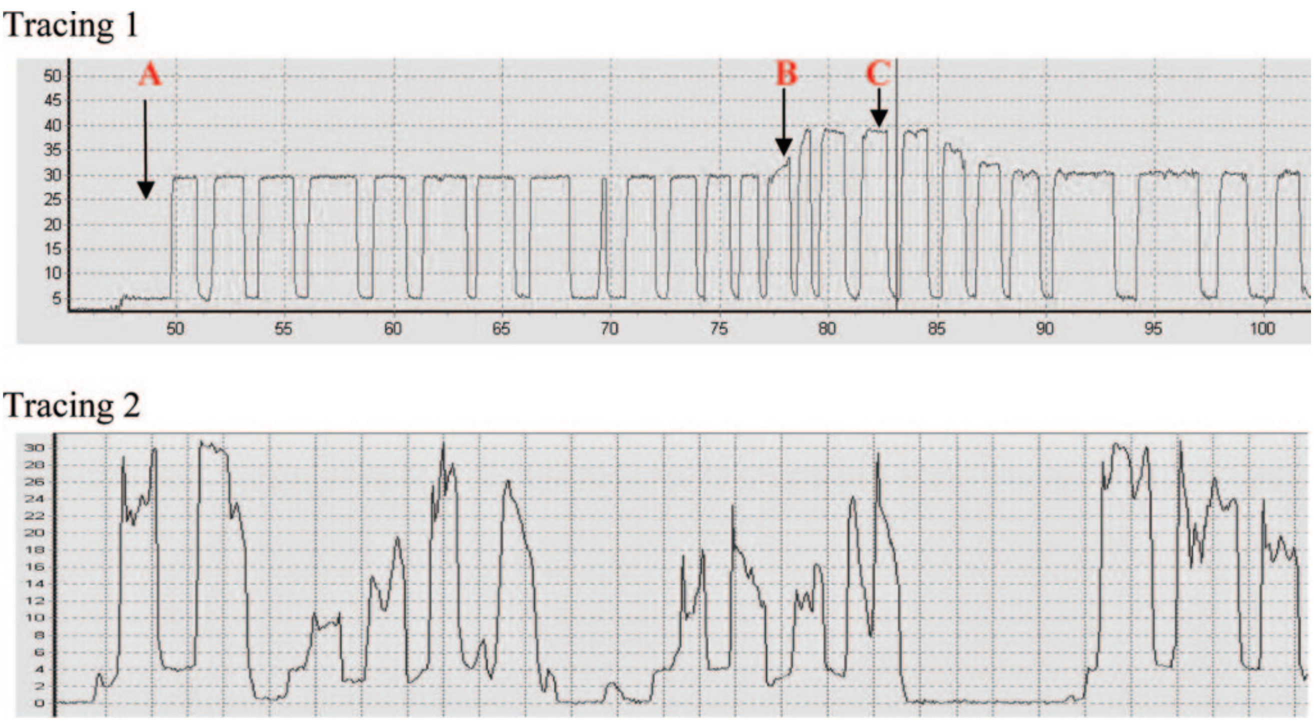

FIGURE 1
Tracing 1, A, mask applied; no PediCap color change until B, when airway pressure was altered by operator. Pedicap changed color at C, and airway pressure rapidly decreased. Tracing 2, Target pressure is not being reached with a pressure plateau and most likely represents a significant gas leak.

experience with >1000 video-recorded resuscitations and still find it difficult to determine whether there is adequate chest movement. The use of plastic wrap, which is routine for our teams in resuscitating the ELBW infants, makes such observations even more difficult. Our resuscitation teams now respond quickly to the lack of detector color change by repositioning the head and/or obtaining an appropriately sized mask as soon as they observe even 3 breaths with no color change during which there was an adequate airway pressure. When an obstructed airway is encountered, the team's responses include additional suctioning and reposition of the head, mask, and jaw. These maneuvers are usually effective, but in some situations, other approaches may be required, such as increasing the ventilating pressure or using a nasopharyngeal tube, oral airway, or finger to separate the tongue from the posterior pharyngeal wall. In the minority of infants, urgent intubation may be required. From our reviews, infants did not demonstrate any significant clinical improvement until their airway was judged to be patent.

ELBW infants are prone to airway obstruction because of their relatively large tongues and small mandibles. Indeed, most apnea in the NICU has an obstructive component,[12] with obstruction occurring at the pharyngeal level.[13] In addition, the larynx closes during central apnea.[14,15] In a previous study to evaluate the natural history of apnea of prematurity, we noted that apnea was frequent during the first 24 hours after delivery and that the majority of these early events had an obstructive component.[16] The data suggest that providing the resuscitator with a signal that indicates that the airway is obstructed will facilitate earlier initiation of appropriate responses.

From our results, we would recommend that the resuscitation team attempt to achieve their target inspiratory pressures as their first goal in providing bag-and-mask resuscitation. Failure to achieve such pressures usually indicates a significant leak, which should be addressed by repositioning of the mask and jaw or selecting a better-fitting mask. Once target pressure has been achieved, the colorimetric detector is useful in determining whether there is airway obstruction, and failure of adequate color change in the face of delivering targeted pressures requires further attention to the airway, including repositioning, suctioning, use of an oral airway or nasopharyngeal tube to attempt to open the pharynx, and use of higher airway pressures. Failure of these interventions requires immediate intubation. Prolonged attempts at ventilation against an unrecognized obstructed airway could result in further, more aggressive and hazardous procedures, such as chest compressions and/or medication administration.

CONCLUSIONS

Airway obstruction, as detected by the use of a colorimetric carbon dioxide detector, occurs in the majority of the VLBW infants who require ventilation with a face mask during resuscitation after delivery. The use of this simple device can alert the resuscitation team to this situation and facilitate maneuvers that can re-establish a patent airway.

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