Evaluating Manual Inflations and Breathing during Mask Ventilation in Preterm Infants at Birth

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Objective To investigate inflations (initial sustained inflations and consecutive inflations) and breathing during mask ventilation in preterm infants at birth.

Study design Resuscitation of infants <32 weeks' gestation receiving mask ventilation at birth were recorded. Recorded waveforms were divided into inflations (sustained and consecutive inflations), breaths in between inflations, breaths coinciding with an inflation, and breaths on continuous positive airway pressure (during evaluation moments in between and after ventilation) and expiratory tidal volume (V_{Te}) was compared. Inflations were analyzed for leak, low V_{Te} (<2.5 mL/kg), high V_{Te} (>15 mL/kg in sustained inflations, >10 mL/kg in consecutive inflations), and airway obstruction.

Results In 27 infants, we analyzed 1643 inflations, 110 breaths in between inflations, 133 breaths coinciding with an inflation, and 1676 breaths on continuous positive airway pressure. A large mask leak frequently resulted in low V_{Te}. Breathing during positive pressure ventilation occurred in 24 of 27 infants (89%). Median (IQR) V_{Te} of inflations, breaths in between inflations, and breaths coinciding with an inflation were 0.8 mL/kg (0.0-5.6 mL/kg), 2.8 mL/kg (0.7-4.6 mL/kg), and 3.9 mL/kg (0.0-7.7 mL/kg) during sustained inflations and 3.7 mL/kg (1.4-6.7 mL/kg), 3.3 mL/kg (2.1-6.6 mL/kg), and 4.6 mL/kg (2.1-7.8 mL/kg) during consecutive inflations, respectively. The V_{Te} of breaths were significantly lower than the V_{Te} of inflations or breaths coinciding with an inflation.

Conclusions We often observed large leak and low V_{Te}, especially during sustained inflations. Most preterm infants breathe when receiving mask ventilation and this probably contributed to the stabilization of the infants after birth. *(J Pediatr 2013;162:457-63)*.

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Approximately 60% of preterm infants receive respiratory support at birth,[1] when adequate ventilation is crucial.[2,3] Frequently, positive pressure ventilation (PPV) administered via a mask is used as the primary intervention. Sustained inflations can be given during the initial support to help aerate the preterm lung at birth,[4] followed by consecutive inflations of shorter duration if required.

The technique of mask ventilation requires considerable practice and experience to apply safely and effectively.[5,6] Successful mask ventilation depends on good technique, the avoidance of large quantities of air leakage from the mask, airway obstruction, and inadequate tidal volumes. However, even among experienced operators, large and variable leaks between the mask and face often occurs in mannequins[5-7] and infants,[8,9] which may lead to inadequate and uncontrolled tidal volume during PPV and result in ineffective ventilation and even injury to the lung.[3,10-12]

Most preterm infants breathe immediately after birth,[13] but this is very difficult to observe when judged solely by chest movements.[14] Their breaths might either contribute to the effect of resuscitation or counteract the inflations. This difficulty in observation prompted us to evaluate the first 5 minutes of mask ventilation in preterm infants after birth. We analyzed all recorded waveforms and evaluated how often inflations were hampered by large quantities of air leakage from the facemask or airway obstruction and how often this led to low or high tidal volumes. We also analyzed all recorded breaths and evaluated how often preterm infants' breathing occurred during PPV and how it related to inflations.

CPAP	Continuous positive airway pressure
GA	Gestational age
NICU	Neonatal intensive care unit
PEEP	Positive end expiratory pressure
PIP	Peak inspiratory pressure
PPV	Positive pressure ventilation
V_{Te}	Expiratory tidal volume
V_{Ti}	Inspiratory tidal volume

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Methods

This prospective observational study was performed at the Department of Neonatology in the Leiden University Medical Center, a tertiary-level perinatal care center. The study was approved by the Institutional Review Board of the Leiden University Medical Center. The use of a resuscitation monitor and oximeter is advised in the neonatal resuscitation guidelines of the Leiden University Medical Center and is considered as standard of care when time allows us to set up the equipment. Parental permission to use the data for research was asked after recording.

From March 2009 to October 2010, consent was asked from parents of consecutively born infants with a gestational age (GA) <32 weeks to make recordings of the resuscitation after birth. Infants were included in the study when PPV via a facemask was given after birth. Recordings were made when time and logistics allowed us to set up the equipment. We excluded infants who received no respiratory support or received continuous positive airway pressure (CPAP) only. We also excluded infants who received PPV via a nasopharyngeal tube because we observed that most infants ventilated via nasal tube breathe out through their mouth, even if the mouth was closed by the resuscitator, and this action influences measured tidal volumes and leak. Both facemask and nasal tube are frequently used interfaces for PPV in the delivery room, and an interface is chosen according to preference of the resuscitator.

Resuscitation was performed with a T-piece infant resuscitator (Neopuff; Fisher & Paykel Healthcare, Auckland, New Zealand) with a round silicone facemask that was the appropriate size for infant's weight (Laerdal, Stavanger, Norway). Infants received heated and humidified gas (MR 850 heated humidifier and 900RD110 humidified resuscitation circuit; Fisher & Paykel Healthcare, New Zealand). The local guideline states that resuscitation should be started with 5 sustained inflations lasting 2-3 seconds, peak inspiratory pressure (PIP) 20 cmH_2O, positive end expired pressure (PEEP) 5 cmH_2O, gas flow rate 8 L/min, and air.[2,15]

Respiratory interventions were recorded with a webcam and a Florian respiratory function monitor (Acutronic Medical Systems, AG, Hirzel, Switzerland), with a hot wire anemometer as flow sensor between the T-piece and facemask (dead space <1 mL) to detect gas flow in and out of the mask. The flow signal was integrated to measure inspiratory and expiratory tidal volume (V_{Ti} and V_{Te}, respectively), and the difference equals the leakage from the mask ($[V_{Ti} - V_{Te}/V_{Ti}] \times 100$).[7] The flow sensor was calibrated before each recording. Pressure was measured from the distal section of the T-piece tubing.

Oxygen saturation and heart rate were measured with a Masimo SET pulse oximeter (Masimo Radical; Masimo Corporation, Irvine, California). Signals of gas flow, tidal volume, ventilatory pressure, tidal volume, oxygen saturation, heart rate, and breathing were digitized and recorded at 200 Hz using Spectra software (Grove Medical, London, United Kingdom).

The use of a respiratory monitor is in our local guidelines, if time allows it to be set up. The resuscitators were not blinded to the respiratory monitor. To minimize bias, the researcher did not inform the resuscitator what the recordings of saturation, heart rate, and respiratory function variables showed.

Demographic data were collected from hospital records. All waveforms during the first 5 minutes of respiratory support were analyzed and categorized into 1 of 3 following respiratory patterns: inflation, breath, or breath coinciding with inflation.

Inflation

Inflation was characterized by an inspiratory flow simultaneous with an obvious increase in airway pressure from inflation. The start of expiratory flow was synchronous with the end of the inflation when airway pressure starts to return to the PEEP pressure (**Figure 1**).[16]

The inflations were divided into initial sustained inflations and the following consecutive inflations. A sustained inflation was defined as a prolonged inflation given at the beginning of respiratory support in the delivery room. Consecutive inflations were defined as inflations of approximately 40-60 per minute (**Figure 1**).

Breath

A breath was characterized by an inspiratory and expiratory flow in absence of a concurrent pressure increment from an inflation. They often were associated with a simultaneous reduction in PEEP (**Figure 2**).[16] Breaths were divided into breaths in between inflations and breaths on CPAP. CPAP was given in between ventilation when there was moment of evaluation or after the ventilation was stopped.

Breath Coinciding with an Inflation

A breath coinciding with an inflation was characterized by a breath adjacent to or during an inflation. There were 2 coincidental inspiratory flow patterns resulting in one volume wave (**Figure 2**).[16] All inflations were analyzed for large mask leakage and low or high tidal volume. We defined large mask leakage as >60% because we found that above this level set pressures were often not reached and tidal volume decreased rapidly. We defined low V_{Te} as <2.5 mL/kg because this is close to dead space ventilation (~2 mL/kg). We defined high V_{Te} as >15 mL/kg in initial sustained inflations and >10 mL/kg in consecutive inflations because V_{Te} is considered harmful when greater than this level.[17,18]

During neonatal resuscitation, obstruction may occur.[5,9] Obstruction could only be observed when leak was minimal because large leak is a confounder to recognizing airway obstruction.[5] Obstruction was calculated from inflations with <30% mask leak. We considered an inflation to be obstructed if there was a reduction in flow and volume and typical flattening of the flow waves when the PIP was unchanged (<25th percentile of mean V_{Te} per infant during inflations <30% leak