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Intratracheal catheter suction removes the same volume of meconium with less impact on desaturation compared with meconium aspirator in meconium aspiration syndrome

Yohei Akazawa, Takefumi Ishida, Atsushi Baba, Takehiko Hiroma, Tomohiko Nakamura *

Department of Pediatrics, Shinshu University School of Medicine, 3-1-1, Asahi, Matsumoto, Nagano, 390-8621, Japan

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ABSTRACT

Objective: To evaluate the impact of suction technique on the rate of meconium removal, oxygenation, and hemodynamics in an animal experimental model of meconium aspiration syndrome (MAS).
Methods: MAS was induced in ventilated rabbits using 3.5 ml/kg of 20% human meconium. Tracheal suction with either catheter suction (CS) or meconium aspirator (MA) was performed after meconium instillation. Percentage of meconium collection rate, PaO_2 trends for 2 h after tracheal suction, and acute-phase SpO_2 trends were compared between CS and the other three groups, the tube was withdrawn while meconium was aspirated with an MA, then the trachea was reintubated 5, 10 or 15 s after suctioning of meconium.
Results: Percentage of meconium collection rate and PaO_2 showed no significant differences between groups. The MA group taking 15 s for reintubation after meconium suctioning, showed a significantly lower acute-phase SpO_2 than the CS group ($P<0.05$). The time for SpO_2 to return to ≥90% was also longer in the MA group taking 15 s for reintubation than in the CS group ($P<0.05$).
Conclusion: Intratracheal CS removed the same volume of meconium with less impact on desaturation compared with meconium aspiration in an animal model of MAS. Intratracheal CS may be benefit to remove meconium in non-vigorous infants with meconium-stained amniotic fluid at birth.

1. Introduction

Meconium aspiration syndrome (MAS) is a common cause of respiratory distress in term and near-term infants [1]. Infants who need intubation and mechanical ventilation due to MAS comprise around 0.43 of 1000 live births and death related to MAS occurs in 0.96 per 100,000 live births [2]. Approximately 8–15% of all infants are born with evidence of meconium-stained amniotic fluid (MSAF) and as many as 2.5–4% of term infants may present with MSAF and less-than-adequate "vigor" [3]. As MAS cannot be prevented in utero, removal of meconium from the trachea as soon as possible after birth is recommended to reduce the severity of MAS [2]. The appropriate intervention for MSAF as recommended by the Neonatal Resuscitation Program (NRP) depends on whether the infant is "vigorous", defined as: 1) strong respiratory efforts; 2) good muscle tone; and 3) heart rate ≥ 100 beats/min. When an infant is vigorous, the resuscitator proceeds with routine management. However, if the infant is not vigorous, the resuscitator inserts a laryngoscope into the larynx and aspirates meconium from within the pharynx and larynx under direct visualization using a 12- or 14-F suction tube. The trachea is then intubated and connected to a meconium aspirator (MA) fitted with a suction tube. The central hole in the MA is closed so that aspiration pressure is applied to the tracheal tube. The tracheal tube is withdrawn while aspiration continues to remove meconium from within the trachea. This process is repeated until either little additional meconium is recovered or until the heart rate of the neonate indicates that resuscitation must proceed without delay [4], so this method necessitates reintubations in infants requiring repeated endotracheal suctioning or management of artificial ventilation. Endotracheal intubation is an invasive procedure that takes experience and skill to master and can be associated with adverse effects including bradycardia, fluctuations in blood pressure, hypoxia and airway injury. Pediatric residents often struggle to master this skill [5]. Intratracheal suction through the endotracheal tube (ETT) that is commonly employed for intubated neonates in the neonatal intensive care unit is widely used to remove intratracheal debris. With this method, the ETT can be left in place after suctioning if necessary, allowing rapid repeated suctioning or a change to artificial ventilation without reintubation. We hypothesized that intratracheal suction with a catheter through the ETT would be associated with less deterioration of neonatal vital signs and the same basic effects compared to repeated intubation for aspiration using an MA. We investigated the effects of both techniques on the removal rate of meconium, oxygenation, and hemodynamics in a rabbit model of MAS.

* Corresponding author. Tel.: +81 263 73 6700.
E-mail address: tnakamura@naganoch.gr.jp (T. Nakamura).

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2. Materials and methods

Forty-eight white Japanese rabbits weighing between 1.8 and 2.3 kg were used in this study. All experimental work was approved by the Institutional Animal Care and Use Committee of Nagano Children's Hospital in Nagano, Japan.

2.1. Meconium preparation

First-pass human meconium was obtained from term, healthy neonates. This meconium was suspended in distillate at a concentration of 20% (weight/volume) and homogenized to break up particles. Aliquots of the 20% meconium solution were stored frozen at −30 °C until use. Before commencing the studies, meconium was thawed at room temperature. The final consistency of the 20% meconium solution was similar to "thick" meconium based on clinical judgment.

2.2. Animal preparation

All animals were premedicated by intramuscular administration of ketamine (10 mg/kg/dose) and xylazine (5 mg/kg/dose). The peripheral ear vein was cannulated using a 24-gauge angiocatheter for intravenous anesthesia and infusion of medication. Animals were placed in a supine position under a radiant warmer to maintain body temperature during the entire study period, and body temperature was monitored using a rectal temperature probe. Tracheotomy was performed, and an ETT with an internal diameter 3.5 mm and no cuff (Portex, Hythe, Kent, UK) was inserted to a depth of 4 cm and secured in place. The lungs were ventilated using a time-cycled, pressure-limited ventilator (Humming II; Metran, Saitama, Japan) with: fraction of inhaled oxygen (FiO_2), 1.0; inspiratory time, 1.0 s; positive end expiratory pressure (PEEP), 5 cmH_2O; peak inspiratory pressure (PIP) to achieve a tidal volume (V_T) of 10 ml/kg which we has been shown to be effective in this meconium aspiration animal model [6] and respiratory rate (RR) adjusted to maintain $PaCO_2$ at 35–45 mmHg. The carotid artery was cannulated for blood pressure measurement and blood sampling. Anesthesia was provided by continuous intravenous infusion of ketamine (5 mg/kg/h) and paralysis was maintained using pancuronium (0.1 mg/kg/h). Arterial oxygen saturation and heart rate were monitored continuously using a transcutaneous pulse oximeter (DDG2001; Nihon-Kohden, Tokyo, Japan) and a systemic artery catheter was connected to a pressure transducer in addition to the electro cardio gram [ECG] signal. These data were displayed on a monitor during experiments and recorded on a computer for subsequent analysis. Systemic arterial blood gases (ABL 700; Radiometer, Copenhagen, Denmark) were analyzed intermittently and the values were corrected to body temperature. V_T was measured intermittently using a low-dead space hot-wire pneumotachograph (Aivision Laminar Flow Meter LFM-317; Metabo, Lausanne, Switzerland). Animals were administered a mixture of 0.45% sterile saline and 10% glucose solution at 3 ml/kg/h during the experiment. Animals were allowed 20 min for stabilization before group allocation, then baseline recordings were taken, with those showing baseline $PaO_2 < 400$ mmHg excluded. After stabilization, a 20% slurry of human meconium (3.5 ml/kg) was infused into the trachea of each animal through the ETT. This method has been used previously and has been established as a reliable model of MAS [6,7].

2.3. Experimental protocol

2.3.1. Series 1: Collection rate of meconium and variations in PaO_2, heart rate, and mean blood pressure for 2 h after meconium suctioning

After meconium instillation, animals were randomly assigned to one of two groups.

1: MA group ($n = 8$). After instillation of meconium, an ETT was intubated through the tracheostomy hole and the tube connected to an MA was withdrawn to aspirate meconium. The trachea was then intubated again. The time from tube withdrawal to reintubation was ≤5 s.
2: Catheter suction (CS) group ($n = 8$). After instillation of meconium, intratracheal aspiration was performed using an 8-F intratracheal suction catheter, while the intratracheal tube was kept indwelling. The suction catheter was passed in a measured way to 0.5 cm below the tip of the ETT.

Suction pressure was −13 kPa and the duration of suction was ≤5 s in each group. To quantify the amount of meconium, we connected a trap between the suction device (ETT or catheter) and suction tube to receive the meconium. After aspiration of meconium, mechanical ventilation was then performed for 2 h in both groups. Conditions of artificial ventilation in both groups were set as follows: PEEP, 5 cmH_2O; inspiratory time, 1.0 s; FiO_2, 1.0; and PIP adjusted to maintain V_T at 15 ml/kg. Respiratory rate was adjusted to maintain $PaCO_2$ between 35 and 45 mmHg. Arterial blood gases were collected starting at baseline and every 30 min from 20 min after meconium aspiration until the end of this experiment. Blood pressure and heart rate were monitored every 30 min for 2 h. At the end of the experiment, animals were euthanized by injection of an overdose of anesthetic.

2.3.2. Series 2: Variations in SpO_2, heart rate, and mean blood pressure during the acute stage after meconium suctioning

After meconium instillation, animals were randomly allocated to one of four groups. For the CS group ($n = 8$), mechanical ventilation was started immediately after recovery of meconium with an 8-F intratracheal suction tube. For the other three groups, the tube was withdrawn while meconium was aspirated with an MA, then the trachea was reintubated 5, 10 or 15 s after suctioning of meconium. These three times from meconium suctioning to reintubation were selected as the times in pilot animal experiment. In reality it may take even longer for each attempt in clinical situation.

1: CS group ($n = 8$)
2: Reintubation 5 s after suction of meconium (MA-05 group, $n = 8$)
3: Reintubation 10 s after suction of meconium (MA-10 group, $n = 8$)
4: Reintubation 15 s after suction of meconium (MA-15 group, $n = 8$)

Suction pressure was −13 kPa and suction duration was ≤5 s in each group. After meconium suctioning, PIP was adjusted to maintain V_T at 15 ml/kg and respiratory rate was increased to 30 breaths/min. Animals were ventilated mechanically for 10 min after meconium aspiration. Arterial oxygenation, saturation, heart rate, and blood pressure were monitored continuously using a pulse oximeter and intravascular sensor during this experiment.

2.4. Statistical analysis

All results are expressed as means ± standard deviation. In the analysis of meconium recovery rate in Series 1, groups were compared using unpaired *t*-tests. Analysis of variance for repeated measures with Scheffe's test was employed for all other data from Series 1 and all data from Series 2. Values of $P < 0.05$ were considered to indicate statistical significance.

3. Results

3.1. Series 1: Collection rate of meconium and variations in PaO_2, heart rate, and mean blood pressure during 2 h of mechanical ventilation after meconium suctioning

Mean percentages of meconium recovered by the MA and 8-F suction catheter were 14.8 ± 5.5% and 19.5 ± 5.0%, respectively. No significant differences were identified between the MA and CS groups.