Improving neonatal resuscitation at birth : technique and devices

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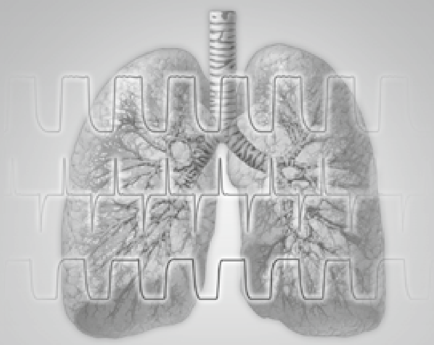

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General introduction, aim and outline of the thesis

General introduction

The transition to extra-uterine life at birth represents one of the greatest physiologic challenges that humans encounter and begins with lung aeration and the onset of air-breathing.[1] Liquid that fills the airways before birth must be cleared immediately after birth to allow the entry of air, the recruitment of a functional residual capacity, and the onset of pulmonary gas exchange. These processes initiate respiratory and cardiovascular responses in the newborn that support the successful transition from foetal to postnatal life. It is now apparent that lung aeration and the onset of pulmonary ventilation trigger such changes. Therefore, adequate ventilation is vital when an infant does not achieve the transition promptly.

Approximately 3–5% of the world's annually born 130–136 million infants and 60% of preterm infants require some resuscitative intervention.[2,3] This makes neonatal resuscitation one of the most frequently performed procedures.[3] In most cases this neonatal 'resuscitation' comprises only the establishment of adequate ventilation.[4,5] Establishing effective ventilation is the key to successful resuscitation. Chest compressions and medication are rarely needed during resuscitation and are often secondary to improper ventilation.[6]

In developed countries, around 5–13% of all live born infants are born preterm.[7] In the Netherlands, preterm live births account for 7.4%. Preterm infants often fail to create functional residual capacity because they have an impaired ability to clear airway liquid.[1,8] The lungs of preterm infants are structurally immature, surfactant deficient and have impaired lung liquid clearance.[9-11] In addition, preterm infants have poor muscle strength, a very compliant chest wall and low compliant lungs.[12] Therefore, preterm infants, more often than term infants, need respiratory support to create and retain functional residual capacity after birth.[1]

In the last decades caregivers have been guided by national and international guidelines and training programs have been set up. The first guidelines for neonatal resuscitation were published in 1979 and were based on opinion and tradition instead of research and experimentation.[13] Through neonatal resuscitation training and the practical use of guidelines, neonatal morbidity and mortality have decreased.[14-16] However, resuscitation guidelines are still based on very little evidence. Our knowledge of neonatal transition is largely based on assumptions and extrapolation from adult data rather than observation and scientific evidence. Over the years, important progress has been made in the treatment of infants at birth. Research on neonatal resuscitation is constantly evolving and guidelines with step-by-step flow charts are now available for caregivers to improve neonatal resuscitation and outcome.

Neonatal resuscitation training programs focus on scenarios and skills and technique of caregivers. However, very little attention is paid to the efficacy of the interventions themselves. Especially the adequacy and efficacy of mask ventilation, the most frequent primary intervention, is currently an under-recognised problem. We are currently not informed whether we under- or over-ventilate preterm infants or whether inappropriate volumes are given. The often immature lungs of preterm infants are highly susceptible to lung injury.[17-20] Injury to the lungs can be caused by overdistension (volutrauma),[21-23] high pressures (barotrauma),[24-27] repeated alveolar collapse and re-expansion (atelectrauma)[18,19,27,28] and high inspired oxygen.[3,18,29-32] There is increasing evidence that, when possible, non-invasive resuscitation methods should be used and intubation with mechanical ventilation should be avoided.[33,34] Although caregivers are familiar with the concept of ventilator induced lung injury and preterm lungs are most vulnerable at birth, so far little effort has been made to determine the adequacy and efficacy of ventilation in the delivery room.

Although there are methods available to assess the efficacy of respiratory support of infants in the neonatal intensive care unit (NICU), most of these methods are not routinely applied in the delivery room. Until 2006, neonatal resuscitation guidelines recommended to assess the adequacy of ventilation in the delivery room by counting the increase in heart rate, observing chest excursions and infant's colour.[35] Since 2010 pulse oximetry is advised as the assessment of infant's colour and counting heart rate were shown to be inaccurate and subjective.[36-39] However, pulse oximetry provides only indirect information about ventilation. In the NICU ventilation is monitored by respiratory parameters (delivered pressures, tidal volume, respiratory rate, presence of spontaneous breathing) and ventilator waveforms. Since 2008, the Leiden University Medical Center has adopted respiratory function monitoring as standard of care in the delivery room. This monitor measures and displays respiratory parameters continuously and gives the caregiver feedback to adjust technique or settings.

Successful neonatal resuscitation depends on using appropriate devices, the right technique and a good strategy. All of these factors should be optimal to ensure a successful resuscitation. There are numerous devices and interfaces available for neonatal resuscitation. In the Leiden University Medical Center, a Neopuff T-piece resuscitator is used as a primary resuscitation device in the delivery room. A T-piece device has several advantages over other devices for neonatal resuscitation, especially in preterm infants.[3,40-46] However, questions still remain on its optimal use and the ideal ventilatory settings of this device have not been established yet. The technique of mask ventilation is difficult and requires considerable practice and experience to apply safely and efficiently, especially to preterm infants. Further studies are needed on optimal mask ventilation technique. A feedback device in the delivery room may improve neonatal resuscitation.

Outline of the thesis

The general aim of this thesis was to evaluate the efficacy and adequacy of ventilation in the delivery room. This thesis comprises manikin studies on how to optimise current resuscitation technique and on the use of available devices. Observational studies were performed to evaluate neonatal resuscitation in the delivery room. In a review at the end of this thesis, the results of our studies will be discussed and compared with other studies in this field. This review provides an update on the current literature and the findings of our investigations into techniques and devices used in neonatal resuscitation practice.

In all of our studies we recorded respiratory interventions were with a Florian respiratory function monitor (Acutronic Medical Systems, AG, Switzerland), using a hot wire anemometer as flow sensor between the T-piece and face mask (dead space < 1 mL) to detect gas flow in and out of the mask. The flow signal is integrated to measure inspired and expired tidal volumes, the difference equals mask leak. Pressure is measured from the distal section of the T-piece tubing.[47] Signals for flow, pressure and volume were digitised and recorded at 200 Hz using Spectra physiological software (Grove Medical, London, UK).

Chapter 1 – General introduction

Part 1 – Technique of neonatal resuscitation at birth

Chapter 2 – A manikin study is presented which evaluates current mask technique and tests the efficacy of training in optimal mask handling technique. Mask leak and airway obstruction with mask ventilation during simulated neonatal resuscitation were measured and compared among three different professional groups before and after training and three weeks later.

Data was gathered in an academic hospital (Leiden University Medical Center in Leiden, the Netherlands) and a regional hospital (Reinier de Graaf Gasthuis, Delft, the Netherlands).

Chapter 3 – International neonatal resuscitation guidelines recommend assessing chest excursion when the heart rate is not improving. However, assessing 'adequate' chest excursion lacks objectivity. The aim of this manikin study was to test the accuracy in the assessment of 'adequate' chest excursions by measuring intra- and inter-observer variability of participants during simulated neonatal resuscitation. For this study, participants mask ventilated two manikins (one highly compliant manikin and one manikin with low lung compliance). The pressure at which participants considered the chest excursions to be 'adequate' was analysed.

This study was performed in collaboration with our colleagues from the Neonatal Research Unit and Institute for Health Research for the University Hospital La Fe in Valencia, Spain.

Chapter 4 – We observed that caregivers press down the mask quite hard in order to reduce mask leak. We investigated the compressive force applied to the head of a manikin during mask ventilation. We determined whether this force increased in response to an attempt to correct mask leak and led to airway obstruction. We also investigated whether the force applied to the head of the manikin was dependent on the resuscitation device used.

Chapter 5 – The difficulties of mask ventilation observed in our manikin studies, prompted us to evaluate mask ventilation in very preterm infants at birth. In this observational study positive pressure ventilation of preterm infants was recorded. We performed a breath-by-breath analysis of the initial sustained inflations and consecutive inflations. We evaluated how often mask ventilation of preterm infants with a gestational age of < 32 weeks was hampered by a large face mask leak or airway obstruction and how often this led to low or high tidal volumes. We also measured heart rate, oxygen saturation and recorded the mode of ventilation when infants were transported to the NICU.

Chapter 6 – The data gathered from the participants of the study presented in chapter 4 was also evaluated for the occurrence of breathing. Breathing is very difficult to observe in preterm infants. It is possible that the breaths contribute to the effect of resuscitation or counteract the inflations. Earlier studies have shown that most very preterm infants breathe immediately after birth.[48,49] The aim of this study was to evaluate how often preterm infants' breathing occurred during positive pressure ventilation and how the breaths related to inflations.

Part 2 – Devices for neonatal resuscitation at birth

Chapter 7 – Neonatal resuscitation guidelines do not specify the gas flow rate that should be used during mask ventilation. It is possible that fast pressurisation of the mask, when using higher gas flow rates, influences the seal between mask and face. The aim of this study was to investigate the effect of a low (5 L/min) or high (10 L/min) gas flow rate on pressures, tidal volumes and mask leak.

Data for this study was gathered in an academic hospital (Leiden University Medical Center in Leiden, the Netherlands) and a regional hospital (Tergooi Ziekenhuis, Blaricum, the Netherlands).

Chapter 8 – When using a T-piece device, resuscitators may try to improve airway pressures by increasing the gas flow rate instead of correcting face mask position. The aim of this study was to measure the effect of changing gas flow during positive pressure ventilation on peak inflating pressure (PIP), positive end expiratory pressure (PEEP), expired tidal volume (V_{Te}) and mask leak. In this study we used four different gas flow rates (5, 8, 10 and 15 L/min). In the first part of the study, participants provided positive pressure ventilation with all four gas flow rates in a random order and pressures were set back to their original setting after each gas flow increment. In the second part of the study, gas flow rate was increased from 5 to 8, 10 and 15 L/min without re-setting the pressures to their original setting. The effects on delivered pressures, tidal volume and mask leak were measured in both studies.

This study was performed in the Royal Women's Hospital in Melbourne, Australia

Chapter 9 – National and international guidelines with step-by-step flow charts on how to perform optimal resuscitation are available for caregivers to improve neonatal resuscitation and outcome. The aim of this study was to evaluate delivery room management of preterm infants in our unit. In Leiden, recording physiological parameters simultaneously with video during neonatal resuscitation is considered as standard of care and is performed when time is available to set up the equipment. With the parent's consent, the recordings are used for training, audit and research purposes. This approach makes it possible to evaluate resuscitation more objectively. Physiological parameters (airway pressures, gas flow, tidal volume, heart rate and oxygen saturation) are measured, use of supplemental oxygen is noted and a video of the resuscitation is recorded. The delivery room management is then evaluated and compared with the local resuscitation guidelines. In addition, use of a respiratory function monitor during resuscitation in the delivery room was evaluated. Results of this study served as an audit to improve neonatal resuscitation practice in our unit.

Chapter 10 – This review forms the general discussion for this thesis. The main results of this thesis will be discussed. It also provides the reader a review of currently used techniques and devices during neonatal resuscitation. This review includes practical advice to caregivers performing neonatal resuscitation of preterm infants at birth. Finally, future perspectives and proposals for future research will be discussed.

Chapter 11 – Summary of the thesis.

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