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Improving neonatal resuscitation at birth : technique and devices

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Auditing resuscitation of preterm infants at birth by recording video and physiological parameters

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Submitted

Abstract

Objective

To evaluate delivery room management of preterm infants in our unit by recording video and physiological parameters and comparing it with the local resuscitation guidelines.

Methods

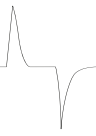
The delivery room management of preterm infants at birth was recorded by an independent researcher. Physiological parameters (airway pressures, gas flow, tidal volume, heart rate and oxygen saturation) were measured, use of supplemental oxygen was noted and a video of the resuscitation was recorded. All signals were digitised and recorded using specially designed software. The delivery room management was then evaluated and compared with the local resuscitation guidelines.

Results

Thirty-four infants were included with a mean (SD) gestational age of 30.6 (3.2) weeks and birth weight of 1292 (570) grams. Time from birth to initial evaluation was longer than recommended (65 (15) seconds). Respiratory support was started at 70 (23) seconds. In 7/34 infants (21%), interventions were performed according to guidelines. In 25/34 infants (74%), one or more respiratory interventions were not performed according to guidelines. In 10/34 infants (29%), one or more non-respiratory interventions (mainly related to the prevention of heat loss) were not performed according to guidelines. The presence and adequacy of spontaneous breathing was difficult to judge clinically. In almost all occasions (96%) the information from the respiratory function monitor was not used.

Conclusions

Neonatal caregivers often deviate from resuscitation guidelines. Respiratory function monitoring parameters were often not used during resuscitation. A difficult part of neonatal resuscitation is subjectively assessing spontaneous breathing.



Introduction

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. Although caregivers are recommended to follow guidelines, the stressful and sometimes unpredictable character of resuscitation can make it difficult to strictly follow guidelines. One study found a significant number of deviations from the Neonatal Resuscitation Program guidelines.¹ Although video recording is considered a useful tool for monitoring,² it is subjective and difficult to judge the adequacy and effect of ventilation. Studies have shown that the judgment of characteristics such as colour, heart rate by auscultation and chest excursions shows large inter- and intrapersonal variability.^{3,4}

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.

The aim of this study was to evaluate the delivery room management of preterm infants by the team in our unit by recording video and physiological parameters and comparing it with the local resuscitation guidelines.

Methods

This prospective observational study was performed in the department for neonatal intensive care of the Leiden University Medical Center, a tertiary level perinatal care centre in Leiden, the Netherlands, with an average of 650 admissions per year.

During the study period our local neonatal resuscitation guidelines were based on international guidelines (ILCOR 2006, European Resuscitation Council 2005),^{5,6} and national guidelines (Dutch Organisation for Paediatrics 2008 guidelines).⁷ The resuscitation algorithm of our local guideline used at the time of the study is shown in figure 1.

To provide respiratory support, it was recommended to start with five initial sustained inflations of 2-3 seconds and if necessary followed by consecutive inflations, using a peak inflating pressure (PIP) of 20 cm H₂O and a positive end expiratory pressure (PEEP) of 5 cm H₂O, a gas flow rate of 8 L/min and air.^{5,7}

Resuscitation was performed by neonatologists, neonatal fellows or supervised registrars



using a flow resistor T-piece infant resuscitator (Neopuff; Fisher & Paykel Healthcare, Auckland, New Zealand) in combination with an appropriate sized Laerdal silicone round mask (Laerdal, Stavanger, Norway) or nasopharyngeal tube (endotracheal tube cut at 7 cm) to deliver non-invasive ventilation. When intubation was required an appropriate sized endotracheal tube was inserted nasally.

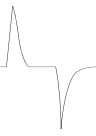
A Florian respiratory function monitor (Acutronic Medical Systems, AG, Switzerland) was used to record respiratory parameters. It uses a small hot wire anemometer as a sensor to detect gas flow. The flow sensor was placed between the T-piece and the facemask. The flow signal was integrated to measure inspired and expired tidal volumes. The hot wire anemometer was calibrated by the researchers each time recordings were made. The pressure sensor was placed in the distal section of the Neopuff T-piece tubing.

Oxygenation and heart rate were measured with a Masimo SET pulse oximeter (Masimo Radical, Masimo Corporation, Irvine CA, USA). The pulse oximetry probe was placed around each infant's right wrist as soon as possible after birth.

Interventions were recorded using a webcam for video monitoring. The video showed only the hands of the caregivers. The parents, obstetric procedures and the faces of the caregivers were not visible.

Signals for gas flow, ventilatory pressure, tidal volume, oxygen saturation heart rate and breathing were digitised and recorded at 200 Hz using Spectra physiological software (Grove Medical, London, UK). For analysis, the inflations were divided into two periods; the initial sustained inflations and the following consecutive inflations. A sustained inflation is defined as a prolonged manual inflation given at the beginning of respiratory support in the delivery room. Consecutive inflations are defined as manual inflations following sustained inflations with a recommended frequency of 40–60/min.

The delivery room management of preterm infants at birth was recorded by an independent researcher, who was not taking part in the resuscitation. We collected gestational age, birth weight and the mode of delivery. The recordings were later evaluated with the team present and their motives for certain actions were discussed. The resuscitation recordings were evaluated against a pre-set checklist that listed the observations/interventions that needed to be performed according to the local resuscitation guidelines.⁷ The resuscitative interventions were split into respiratory and non-respiratory interventions and compared with the flow chart in our local guideline for neonatal resuscitation. Heart rate, breathing



and oxygen saturation were recorded directly after birth and at the start of each new action in the resuscitation. According to the guidelines clinicians should assess the condition of the neonate every 30 seconds in order to evaluate the effect of an intervention and to determine the necessity of a following intervention.

We recorded the following respiratory interventions: positive pressure ventilation (PPV: sustained inflations and consecutive inflations), number and duration of initial sustained inflations, starting oxygen concentration, ventilatory pressures (PIP and PEEP), pressure increments, continuous positive airway pressure (CPAP), and the following non-respiratory interventions: prevention of hypothermia, suctioning, repositioning, endotracheal intubation and chest compressions.

Using a respiratory function monitor is in our local guidelines, if time allows it to be set up. The resuscitators were not blinded to the Florian respiratory function monitor. The researcher was not a member of the team, did not take part in the resuscitation and did not inform clinicians of the information presented on the monitor.

At the end of the study period the team members were asked to fill in a short questionnaire concerning the use of the Florian respiratory monitor (addendum 1). We chose to do this at the end of the study period to ensure that the use of the monitor would not be influenced by the questionnaire.

Data were analysed using SPSS (SPSS for windows, version 16.0, 2008, Chicago, Ill., USA). Results are presented as mean (standard deviation (SD)) for normally distributed continuous variables and median (interquartile range (IQR)) for variables with a skewed distribution. A p value < 0.05 was considered statistically significant. Reported p values are two-sided.

The study was approved by the Ethics Review Committee of our hospital. Parental consent to use the data from the recordings was obtained soon after birth.

Results

From January until July 2010, 34 resuscitations of preterm infants at the Leiden University Medical Center were observed and recorded by the researchers. Of those 34 infants, 23 infants (67.6%) were born by caesarean section. The mean (SD) gestational age was 30.6 (3.2) weeks with a mean (SD) birth weight of 1292 (570) grams. Median Apgar scores at one and five minutes were 5 (3-6) and 7 (6-8).

In 7/34 infants (21%), delivery room management was exactly according to guidelines. In 10/34 infants (29%), one or more non-respiratory measures were not performed according to guidelines; these mainly occurred for the prevention of heat loss and the timing of the steps in the resuscitation algorithm. In 25/34 infants (74%), one or more respiratory interventions were not according to guidelines.

Guidelines at Step A: to be performed within 30 seconds from birth (figure 1)

Guidelines indicate that measures to prevent hypothermia should be performed within 30 seconds after birth. All infants in the study were placed under a radiant heater and on a resuscitation table with a heated mattress within 30 seconds. A hat was placed on all infants, but in 7/34 infants (21%) it was not placed immediately after birth. Seven infants were born < 29 weeks' gestation, 6 (86%) of which were correctly wrapped in a polyethylene skin wrap. The seventh infant was dried and wrapped in blankets. Twenty-seven infants were born > 29 weeks' gestation, 8 (30%) of which received a polyethylene wrap whereas the other 19 (70%) were correctly wrapped in blankets and dried according to guidelines.

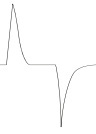
Seven out of 34 infants (21%) received suctioning which was performed in accordance with guidelines.

According to our guidelines breathing and heart rate are used to evaluate the condition of the baby within 30 seconds after birth. However, none were done by this time. Rather the mean (SD) time from birth to evaluation of heart rate by auscultation was 65 (15) seconds. The mean time caregivers used to evaluate heart rate by auscultation was 6 (3) seconds.

Guidelines at Step B: to be performed within one minute after birth (figure 1)

According to our guidelines, if respiratory support is necessary it should be started within one minute after birth. The mean (SD) time from birth to the start of respiratory support was 70 (23) seconds. From our video recordings we found that, in some cases, caregivers did not evaluate the condition of the infant (e.g. listen to heart rate, evaluate breathing) as a first action directly after birth and so skipped the first part of the resuscitation algorithm.

After clinical evaluation, 9/34 infants (26%) had a heart rate > 100 beats per minute and breathed spontaneously and adequately. Of these infants, 1 infant received CPAP outside the guidelines. The others did not receive any respiratory support as recommended by the guidelines.



In 1/34 infants (3%), heart rate was > 100 beats per minute but the infant did not breathe. The caregiver gave sustained inflations, in accordance with the guidelines.

Six infants (18%) had a heart rate < 100 beats per minute and breathed spontaneously. Although the guidelines advise to start respiratory support, these infants received none.

Of the 18/34 infants (53%) that had a heart rate < 100 beats per minute and no spontaneous breathing, 16 received sustained inflations in accordance with the guidelines however 2 received CPAP despite prolonged apnoea.

Inflations (sustained and consecutive inflations) were given to 23/34 infants (68%); 17/23 infants received sustained inflations directly after birth and 6/23 infants received inflations after receiving CPAP first. In all these 23 infants ventilation was correctly started in air (21% O₂).

In 18/23 infants (78%) resuscitation was started with sustained inflations which is in accordance with the guidelines. Nine different combinations in number and duration of sustained inflation were observed. The combinations varied from applying 1–9 sustained inflations that last 2–10 seconds (table 1). Only 8/23 infants (35%) were given sustained inflations that were according to the guidelines (five sustained inflations lasting 2–3 seconds). In 5/23 infants (22%) sustained inflations were not given and infants were immediately ventilated with regular PPV.

Table 1. Number and duration of sustained inflations given to neonates during resuscitation.

Number x duration of SIs given in seconds	Number (%) of neonates
5 x 2-3	8 (35%)
1 x 10	3 (13%)
2 x 7	1 (4%)
3 x 3	1 (4%)
4 x 3	1 (4%)
6 x 3	2 (9%)
9 x 3	1 (4%)
9 x 2	1 (4%)
6 x 1	1 (4%)
None given	4 (17%)

SIs = sustained inflations

In 7/23 infants (30%) ventilation was ineffective judged by the effect on heart rate, oxygen saturation and the clinical condition of the infant. Three infants were repositioned, in 2

infants another size of face mask was chosen and all 7 infants received suctioning and increased ventilatory pressures.

Of the 23 infants that received inflations, 9 were ventilated with the set PEEP as recommended by the guidelines (5 cm H₂O). Mean PEEP was 5.5 (1.7) cm H₂O ranging from 2–10 cm H₂O. The starting PIP was not in accordance with the guideline's suggested 20–25 cm H₂O; in 2/23 infants (9%) mean initial PIP was 20.9 (2.5) cm H₂O ranging from 17–28 cm H₂O.

Six out of 34 infants (18%) were intubated at birth. Of these infants, 2/6 infants (33%) were unnecessarily intubated because they had adequate heart rate, breathing and oxygen saturation (> 70%) at the time of intubation. The caregiver stated to have judged the breathing as insufficient, while respiratory recordings showed the infant's breathing to be adequate. In the remaining 4 infants, intubation was performed in accordance to the guidelines (PPV ineffective, breathing absent, prolonged ventilation required).

Guidelines at Step C: when heart rate < 60 beats per minute (figure 1)

One infant in the study received chest compressions and this was performed in accordance with the guidelines. The combination ventilation:compressions was 1:3 which was according to the guidelines. However, chest compressions were applied with one index finger whereas the guideline advises to compress the chest with two thumbs or two fingers.

Use of respiratory function monitor

In almost all occasions (96%) caregivers indicated they did not use the monitor for evaluating mask technique and in all occasions ventilation pressures were not adjusted based on tidal volumes and mask leak displayed on the monitor. In 90% of resuscitations the information from the monitor was not used for decisions, however in 4% of resuscitations the monitor was used for evaluating spontaneous breathing. All caregivers indicated that they evaluated chest excursions, rather than the monitor, to adjust peak pressures.

Most caregivers find the respiratory function monitor useful, but in practice they found it difficult to incorporate the information during resuscitation. They all indicated that extra training or an extra person reading the monitor would be necessary.

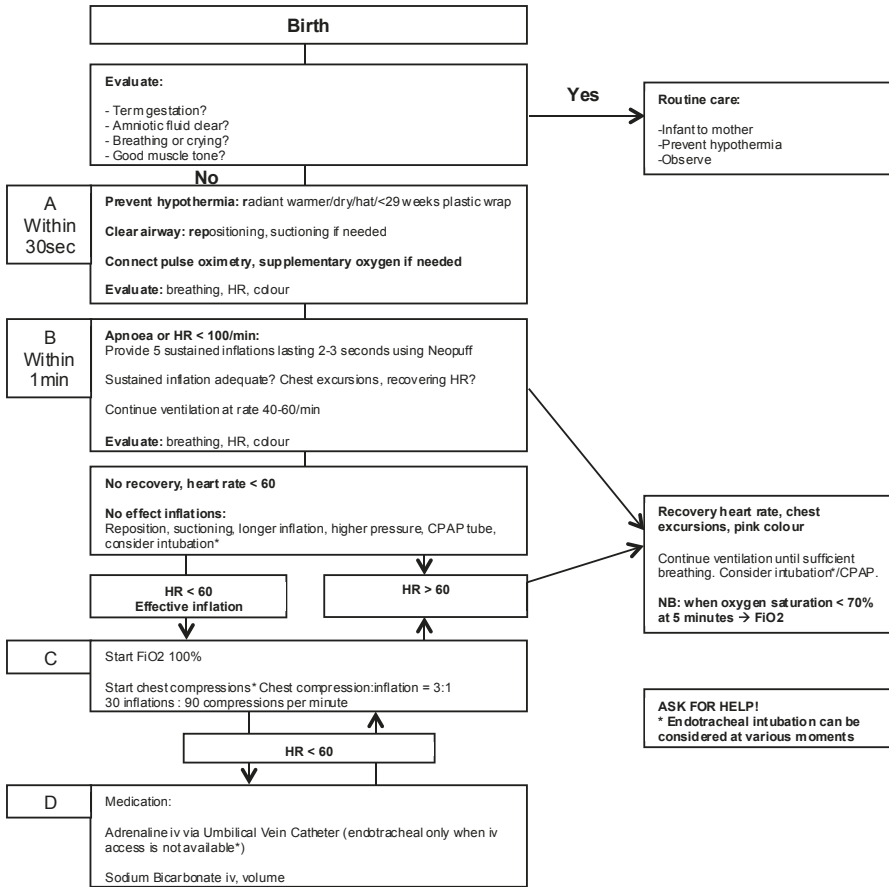
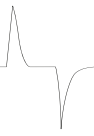



Figure 1: Leiden University Medical Center flow algorithm for resuscitation of neonates at birth. HR: heart rate, CPAP: continuous positive airway pressure, FiO₂: fractional inspired oxygen.

Discussion

In this study, we found that caregivers often do not follow the neonatal resuscitation guidelines and only 21% of infants were resuscitated strictly according to the guidelines. Deviations from the guidelines mainly occurred within the first 30 seconds after birth (Step A of the recommended guidelines) and in the way ventilation was given. Results from this audit emphasised that caregivers needed more time for the initial steps in the resuscitation algorithm and the evaluation of the condition of the infant than the currently recommended 30 seconds. We realise that this time limit is given as an indication, however it may cause caregivers to rush into making decisions to complete the required procedures and assessments within the time restraints. An example is how little time

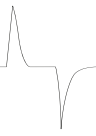


caregivers took to evaluate heart rate (6 (3) seconds). The time required to perform Step A could be influenced by the time the obstetricians needed to cut the umbilical cord and therefore caregivers had less than 30 seconds to complete the first step of the algorithm. To ensure infants are properly assessed and treated at birth, we suggest removing this initial time indication of Step A in the resuscitation algorithm or expanding it to 1 minute. At Step B of the resuscitation guidelines, deviations occurred in treating infants with a heart rate < 100 beats per minute who breathed spontaneously (6/34 infants). Although guidelines advised to start ventilation, caregivers decided not to give respiratory support. Evidence to support this decision is found in Dawson et al. who described that a large portion of term infants, who did not need any resuscitation, had a heart rate < 100 beats per minute in the first minutes after birth (61% at one minute after birth and 21% at two minutes).⁸ According to guidelines, the decision on whether to start inflations is made within one minute after birth, whereby approximately two thirds of infants with a physiological post-partum rise in heart rate would receive unnecessary ventilation. We suggest that the decision to initiate ventilation should incorporate other evaluative parameters such as tone, oxygen saturation and breathing. Also, the time point of when assisted ventilation should be initiated should be reconsidered.

The other major deviation from the resuscitation guidelines occurred in the type of ventilation provided for the infant. According to our resuscitation guideline ventilation should be started with sustained inflations.⁹ Few data exist that describe the ideal characteristics (number and duration) and the effects of sustained inflations.¹⁰⁻¹⁴ Recent clinical and experimental studies have used inflation duration of 10–20 seconds with a positive effect.¹¹⁻¹³ The many different combinations of sustained inflations observed in our study emphasise the importance of determining the appropriate number and duration of sustained inflation to be applied.

In this study, 6 infants were intubated while 2 of those infants had adequate heart rate, breathing and oxygen saturation. One infant received CPAP despite adequate heart rate, breathing and oxygen saturation. We found that breathing was difficult to observe accurately in preterm infants and clinicians often failed to identify and quantify it. Currently, breathing is evaluated by identifying chest excursions. This is, however, very subjective and shows large inter- and intra-personal variability.³ A respiratory function monitor may add objectivity to the assessment of spontaneous breathing and thereby prevent infants from being ventilated unnecessarily.¹⁵

We recently introduced a respiratory function monitor in our local guidelines. Although the benefit of a respiratory function monitor has not yet been shown in a randomised controlled trial, we reasoned that it is easy to use, was non-invasive and the extra objective respiratory measurements, which are well understood in the neonatal intensive care



unit, will help the caregiver make accurate decisions in accordance to the resuscitation algorithm. After the audit period it appeared that caregivers hardly used the monitor for evaluation. We concluded that most caregivers were unfamiliar with using a respiratory function monitor during resuscitation. Although it seems as if caregivers are accustomed to looking at several monitors in the neonatal intensive care unit, they are not accustomed to integrating the information from a respiratory monitor during resuscitation in the delivery room. Students are trained to perform appropriate resuscitation in the delivery room by primarily focusing the infant for clinical signs and not so much on incorporating the feedback from a respiratory monitor with the clinical signs observed. Future training should incorporate consulting the respiratory function monitor for feedback to assess the effectiveness of ventilation. This will be difficult to implement immediately and will probably require time to be integrated as well as time to redesign current training courses. This study was performed when we had just started a neonatal resuscitation audit in our hospital. We will use the results of this study to create awareness among caregivers about what happens during in the delivery room during neonatal resuscitation and how their actions and decisions compare to the neonatal resuscitation guidelines. With this audit we hope to improve neonatal resuscitation in our hospital.

Conclusion

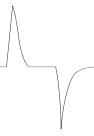
Caregivers deviate from resuscitation guidelines for many reasons. Our study suggested that more time is needed for the initial steps in the resuscitation algorithm and the evaluation of the condition of the infant. At one minute, caregivers are supposed to make the decision on whether to start ventilation. According to recent data, when following these guidelines approximately two thirds of infants would receive unnecessary ventilation. The recommended timing for interventions in the guidelines seemed to be too short and possibly, for some interventions, also too soon. Another difficulty is the judgment of the presence and adequacy of spontaneous breathing. A respiratory function monitor may add objectivity to this judgment and thereby improve the quality of resuscitation.

Acknowledgement

The authors thank Mirjam Mulders for her help with gathering the data.

Addendum 1

1. During resuscitation I evaluate mask technique using the respiratory function monitor:
 - a. Never
 - b. Sometimes
 - c. Often
 - d. Always
2. I adjust pressures according to the volumes I see on the respiratory function monitor:
 - a. Never
 - b. Sometimes
 - c. Often
 - d. Always
3. When making a decision on the course of action I consider the information shown on the respiratory function monitor:
 - a. Never
 - b. Sometimes
 - c. Often
 - d. Always
4. When I am not sure whether the infant breathes spontaneously, I look at the respiratory function monitor:
 - a. Never
 - b. Sometimes
 - c. Often
 - d. Always
5. I use a level of PIP based on:
 - a. The respiratory function monitor
 - b. Chest excursions and heart rate
6. I think volume measurements as an extra parameter are useful:
 - a. Never
 - b. Sometimes
 - c. Often
 - d. Always
7. I think I am sufficiently trained and capable to interpret the flow and volume waves shown on the respiratory function monitor:
 - a. Yes
 - b. No



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