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Predictors of 24-h outcome in newborns in need of positive pressure ventilation at birth

J.E. Linde[a,c,*,2], J.M. Perlman[b,1], K. Øymar[a,2], J. Schulz[a,c,3], J. Eilevstjønn[d,4], M. Thallinger[e,5], S. Kusulla[f,6], H.L. Kidanto[g,7], H.L. Ersdal[a,c,8]

[a] Stavanger University Hospital, Norway
[b] Department of Pediatrics, Weil Cornell, NY, USA
[c] University of Stavanger, Norway
[d] Laerdal Medical/Global Health, Stavanger, Norway
[e] Oslo University hospital, Norway
[f] Haydom Lutheran Hospital, Tanzania
[g] Muhimbili National Hospital, Tanzania

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ABSTRACT

Background: Birth asphyxia, defined as 5-minute Apgar score < 7 in apneic newborns, is a major cause of newborn mortality. Heart rate (HR) response to ventilation is considered an important indicator of effective resuscitation.

Objectives: To describe the relationship between initial HR in apneic newborns, HR responses to ventilation and 24-h survival or death.

Methods: In a Tanzanian hospital, data on all newborns ≥34 weeks gestational age resuscitated between June 2013-January 2017 were recorded using self-inflating bags containing sensors measuring ventilation parameters and expired CO_2, dry-electrode electrocardiography sensors, and trained observers.

Results: 757 newborns of gestational age 38 ± 2 weeks and birthweight 3131 ± 594 g were included; 706 survived and 51 died. Fetal HR abnormalities (abnormal, undetectable or not assessed) increased the risk of death almost 2-fold (RR = 1.77; CI: 1.07, 2.96, p = 0.027). For every beat/min increase in first detected HR after birth the risk of death was reduced by 2% (RR = 0.98; CI: 0.97, 0.99, p < 0.001). A decrease in HR to < 100 beats/minute when ventilation was paused increased the risk of death almost 2-fold (RR = 1.76; CI: 0.96, 3.20, p = 0.066). An initial rapid increase in HR to > 100 beats/min in response to treatment reduced the risk of dying by 75% (RR = 0.25; CI: 0.14, 0.44, p < 0.001). A 1% increase in expired CO_2 was associated with 28% reduced risk of death (RR = 0.72; CI: 0.62,0.85, p < 0.001).

Conclusions: The risk of death in apneic newborns can be predicted by the fetal HR (absent or abnormal), initial newborn HR (bradycardia), and the HR response to ventilation. These findings stress the importance of reliable fetal HR monitoring during labor and providing effective ventilation following birth to enhance survival.

A Spanish translated version of the abstract of this article appears as Appendix in the final online version at https://doi.org/10.1016/j.resuscitation.2018.05.026

* Corresponding author at: Department of Pediatrics, Stavanger University Hospital, POB 8100, 4068 Stavanger, Norway.
E-mail addresses: joga@sus.no (J.E. Linde), jmp2007@med.cornell.edu (J.M. Perlman), knut.oymar@sus.no (K. Øymar), jorn.schulz@sus.no (J. Schulz), joar.eilevstjonn@laerdal.com (J. Eilevstjønn), monica.thallinger@ous.no (M. Thallinger), kusullasimeon@gmail.com (S. Kusulla), hkidanto@gmail.com (H.L. Kidanto), hege.ersdal@safer.net (H.L. Ersdal).
[1] Department of Pediatrics, Weill Cornell Medical College, 525 East 68th Street, New York, NY 10065, USA.
[2] Department of Pediatrics, Stavanger University Hospital, Norway.
[3] Department of Research, Stavanger University Hospital, Norway.
[4] Department of Research, Laerdal Medical/Laerdal Global Health, Norway.
[5] Division of Pediatric and Adolescent Medicine, Oslo University Hospital, Norway.
[6] Department of Mother and Child Health, Haydom Lutheran Hospital, POB Private Bag, Manyara, Tanzania.
[7] Department of Mother and Child Health, Ministry of Health, Dar Es Salaam, Tanzania.
[8] Department of Anaesthesiology & Intensive Care, Stavanger University Hospital, POB 8100, 4068 Stavanger, Norway.

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Background

Although the majority of newborns initiate spontaneous respiration shortly after birth, approximately 8–10% require stimulation and/or brief suctioning, and another 3–6% need positive pressure ventilation (PPV) [1,2]. The recent International Liaison Committee on Resuscitation (ILCOR) guidelines recommend initiating PPV within the first minute after birth if the heart rate (HR) is < 100 beats per minute (bpm) and in apneic newborns [3]. Birth asphyxia secondary to interruption of placental blood flow is the most frequent cause of an absence of spontaneous respirations at birth [4]. Newborns may be in primary apnea with HR < 100 bpm and respond to stimulation and suctioning with the onset of respirations and an increase in HR to > 100 bpm. Newborns born in secondary apnea with the HR < 60 bpm will only respond to the additional intervention of PPV with an increase in HR > 100 bpm, and a longer time to initiation of spontaneous respirations [5].

Implementation of the Helping Babies Breathe program in Tanzania reduced 24-h newborn deaths by 47% [6]. This was especially notable in non-breathing newborns who responded to stimulation, and to a lesser extent in newborns needing PPV to initiate spontaneous respirations. We have recently reported on the importance of providing adequate tidal volumes (TV) to achieve a rapid increase in HR in non-breathing newborns [7]. There are however limited data on the relationship between initial HR at birth (potentially reflecting primary or secondary apnea), delivery of effective ventilation (influenced by several variables e.g. inflating pressure, delivered TV, and mask leak), the HR responses to ventilation, and the subsequent impact on outcome, i.e. survival or death in the first 24 h.

The ability to monitor immediate HR at birth, the HR responses to inflating pressure and delivered TV, as well as expired CO_2 and other ventilation characteristics, has provided the opportunity to assess the critical role of effective ventilation as it relates to a rapid and sustained increase in HR, the subsequent recovery of spontaneous respirations and eventual survival or death.

The aim of this study was to describe the association between initial HR in apneic newborns, the responses in HR to delivered ventilation and to survival or death at 24 h.

Methods

Setting

This descriptive study, performed from July 2013 to January 2017, is part of the Safer Births (www.saferbirths.com) project on stabilization and resuscitation of newborns in a low-resource setting, conducted at the maternity ward of Haydom Lutheran Hospital in rural Tanzania. About 4500 newborns are born in the hospital every year. Midwives and nursing students conduct deliveries and doctors perform caesarean sections when indicated. All midwives were trained in Helping Babies Breathe with the goal of initiating PPV within the "Golden Minute", and chest compressions are not included [6]. In general, there is a single provider, usually the delivering midwife who initiates resuscitation. Non-medical research assistants (n = 18) have been trained and continually retrained to observe and document every hospital delivery. Two or three observers work in three shifts to cover every delivery in the hospital.

Equipment

A newborn resuscitation monitor (Laerdal Global Health, Stavanger, Norway) with the capability to simultaneously measure ventilation parameters (e.g. TV, mask leak, inflation pressure, ventilation rate), expired CO_2, and ECG signals is described in detail elsewhere [8]. Ventilation data were collected through sensors for flow, CO_2 and pressure connected between the mask and bag, and data from each inflation/exhalation were recorded. HR was collected with dry-electrode ECG through a sensor connected to the newborn resuscitation monitor. The newborn resuscitation monitor was available above the resuscitation table in all delivery rooms and in the operation theatre. PPV was performed with a standard bag-mask (Laerdal Medical, Stavanger, Norway) or an Upright bag-mask (Laerdal Global Health, Stavanger, Norway) without Positive End Expiratory Pressure (PEEP) valve or external gas source [9].

Subjects and data collection

All newborns ≥34 weeks gestational age who received bag-mask ventilation after birth with registered HR and ventilation signals were included. The midwives delivered the newborn, dried thoroughly and stimulated if indicated, cut the cord, and unresponsive/non-breathing newborns were brought to the resuscitation table with least possible delay. At the resuscitation table, the HR sensor was applied over the abdomen of the newborn, and the HR appeared on the newborn resuscitation monitor screen in front of the provider where it could be used as an aid to guide their actions.

Ventilation characteristics, expired CO_2, and ECG recordings were downloaded from the newborn resuscitation monitor. Observational data, timing of birth events, procedures and outcome observed and recorded by research assistants were double entered and matched with data from the newborn resuscitation monitor. The ECG recordings were based on zero-crossing counts algorithm and were additionally measured and analyzed for HR [10]. Two of the investigators (JEL and JE) manually examined all ECG readings and detection of QRS complexes crosschecking and correcting errors induced by movements of the newborns (e.g. during stimulation).

Covariates

During labor, research assistants observed and noted obstetrical information (e.g. fetal HR (abnormal defined as < 120 or > 160 bpm), labor complications, mode of delivery, time of birth events (from birth to cord clamp and start of ventilation and duration of resuscitation), newborn characteristics, and newborn outcome at 30 min and 24 h [1].

The covariates are: Newborn and birth characteristics: *An abnormal/undetectable or a fetal HR not assessed before delivery* (yes versus no), these were combined to asses a high risk fetus in the second stage of labor; *First detected HR* (bpm) upon arrival at the resuscitation table; *Birthweight* (gram); *Gender* (male as the reference); and *Caesarean section* (yes versus no). Ventilation characteristics: *Time to start ventilation* (seconds) after birth; *Rate of inflation* (inflations/min); *tidal volume* (ml/kg) given as a median of all inflations; and *Peak inflation pressure* (cm H_2O). Response to treatment characteristics: *Expired* CO_2 (% of expired air); *Unstable HR* (no versus yes) defined as HR dropping to < 100 bpm during interruption of PPV on one or several occasions; and *Time from start of PPV until respiration or cessation in ventilation* (seconds). We analyzed the group of newborns with the first detected HR < 100 bpm to study the impact of *Initial HR increase response* (no versus yes) defined as a positive change in HR to > 100 bpm within 40 s after start of treatment [11].

The endpoint was 24-h newborn outcome; survival or death.

Statistical analyses

Descriptive statistics were used to present descriptive characteristic as median (quartiles) unless otherwise stated. Chi-square calculations and independent-samples Mann-Whitney U test were utilized to compare groups (survivors versus deaths) both for the full duration of the PPV (from first to last inflation) and for the first minute providing PPV.

A Poisson regression model [12,13] with a robust error variance was utilized to describe the associations between the risk of dying and the covariates describing initial newborn status (newborn and birth