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The first breath during resuscitation of prematurely born infants

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ABSTRACT

Background: The first five initial inflation pressures and times during resuscitation of prematurely born infants are frequently lower than those recommended and rarely result in tidal volumes exceeding the anatomical dead space. Greater volumes were produced when the infant was provoked to inspire by an inflation (active inflation).
Aims: To assess factors associated with a shorter time to the first active inflation.
Study design: Respiratory function monitoring was undertaken during resuscitation, peak inflation pressures (PIP), inflation times and the infant's respiratory activity were simultaneously recorded.
Subjects: Infants with a gestational age < 34 weeks requiring resuscitation at birth.
Outcome measures: The relationships of the PIP and inflation time of the first five inflations and first active inflation to the time to the first active inflation.
Results: Recordings from 47 infants, median gestational age of 29 (23–34) weeks, were analysed. The median PIP of the first five inflations was 27 (range 9–37) cmH_2O and inflation time 1.22 (range 0.32–4.08) s. The median PIP of the first active inflation was 25 (range 19–37) cmH_2O and inflation time 1.35 (0.35–3.67) s. The median time to the first active inflation was 7 (range 0–50) seconds and was inversely correlated with the PIP ($p = 0.001$) and inflation time ($p = 0.018$) of the first five inflations and the PIP ($p = 0.001$) and inflation time ($p = 0.008$) of the first active inflation.
Conclusion: The magnitude of the inflation pressures and times of the first five inflations inversely correlate with the time to the first breath during resuscitation.

1. Introduction

Respiratory function monitoring during the initial resuscitation of prematurely born infants has demonstrated that the inflation pressures and times delivered are variable [1] and frequently lower than those recommended [2], resulting in expiratory tidal volumes less than the anatomical deadspace [1]. Expired tidal volumes, however, were significantly greater if the infant inspired during the inflation [1]. We use the term "active inflation" for the occurrence of an infant's inspiration occurring during a positive pressure inflation [1]. In a subsequent study, in the presence of minimal leak (<10%), expiratory tidal volumes were significantly higher both for an initial sustained (2-3 s) inflation and subsequent inflations that coincided with spontaneous breathing [3]. Indeed, one study [4] found that a sustained lung inflation was only successful when accompanied by an inspiratory effort by the infant, that is larger tidal volumes were produced and establishment of a larger fraction of the FRC gain. End tidal carbon dioxide ($ETCO_2$) levels have also been shown to be significantly higher with an active inflation [5,6].

Head demonstrated that if vagal conduction was blocked, rapid inflation, instead of producing apnoea, resulted in stronger and more pronounced diaphragmatic contraction [7]. This was named Head's paradoxical reflex and has been suggested to be the mechanism by which the first functional residual capacity appears. Hoskyns et al. investigated the respiratory reflex responses to resuscitation in 21 preterm infants requiring endotracheal resuscitation at birth [8]. They found that despite mean inflation pressures of 27.3 cmH_2O, inspiratory tidal volumes were often <4.4 ml/kg i.e. less than twice the anatomical dead space [8]. When, however, Head's paradoxical reflex was stimulated, inspiratory volumes exceeded 4.4 ml/kg on 14 occasions compared to only four when the reflex was not stimulated. The first active inflation [1], we suggest is a manifestation of Head's paradoxical reflex, which is more frequent if there is low lung compliance [9]. Hence, we hypothesized that the time to the first active inflation would be influenced by the initial inflation pressures and times of the first five inflations, the

Abbreviations: PIP, peak inflation pressure; $ETCO_2$, end tidal carbon dioxide; RFM, respiratory function monitor; CO_2, carbon dioxide;; RCT, randomised controlled trial.

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initial pressure and time of the first active inflation, the infant's gestational age and whether they had been exposed to antenatal steroids. The aim of this study was to determine if those factors were significantly associated with the time to the first active inflation, as such information could be used to improve the efficacy of resuscitation.

2. Methods

Respiratory function monitoring recordings made during the resuscitation of infants born <34 weeks of gestational age born at Kings College Hospital NHS Foundation Trust between 2012 and 2014 were examined. This group of infants were targeted as they are more likely to require resuscitation than more mature, prematurely born infants. Ethical approval was given for the respiratory function monitoring by the Outer North London Ethics Committee. The Committee required written parental consent only for the analysis of the data, consent was obtained when the mother had been transferred to the postnatal ward.

2.1. Resuscitation protocol

Clinicians taking part in the resuscitations were all trained in newborn life support. As per the perinatal unit's policy, they were encouraged to follow the Neonatal Life Support guidelines [2] that is to use inflation pressures of 20 cmH_2O and a positive end expiratory pressure of 5 cmH_2O, i.e. a peak inflation pressure (PIP) of 25 cmH_2O for the first five inflations each of which was to be maintained for 2 to 3 s. The inflation pressures were then to be increased if chest movement was considered to be inadequate by the clinical team. The clinicians had access to the "in real" time respiratory function monitoring outputs, but these were introduced as part of a research study, hence clinicians were encouraged to undertake resuscitation according to their newborn life support training. Positive pressure ventilation was delivered by a t-piece device (Neopuff Infant resuscitator, Fisher & Paykel Healthcare, Auckland, New Zealand). Infants were usually resuscitated via a facemask, but were immediately intubated if the infant had a heart rate of <60 beats per minute and no respiratory effort as determined by clinical observation.

2.2. Monitoring equipment

NM3 respiratory profile monitors (RPM) (Philips Respironics, Pennsylvania, USA) were used. The monitor was connected to a Dell Latitude Laptop with customised Spectra software Version 3.0.1.4 (Grove Medical, London, UK). The NM3 has a combined pressure, flow, tidal volume and carbon dioxide (CO_2) sensor (dead space 0.8 ml). The sensor was placed between the t-piece device and mask or endotracheal tube. The NM3 monitor is automatically calibrated for flow, pressure and CO2 according to the factory-stored calibration in the monitor. According to the manufacturer's information, the accuracy of the flow sensor was ±3% and the airway pressure was ± 2%. The pressure transducer was automatically 'zeroed' to correct for changes in ambient temperature. The clinicians had been trained to use the respiratory function monitor (RFM), which was set up prior to the delivery.

2.3. Data collection

The infant's gestational age and whether they had been exposed to antenatal steroids were determined by review of the medical notes.

2.4. Analysis

The recordings were examined to identify the infant's first breath (Fig. 1), in all cases the infant's first breath coincided with an inflation (active inflation). The time from commencement of resuscitation to the first active inflation was determined, as were the PIP and inflation time of the first five inflations and the first active inflation.

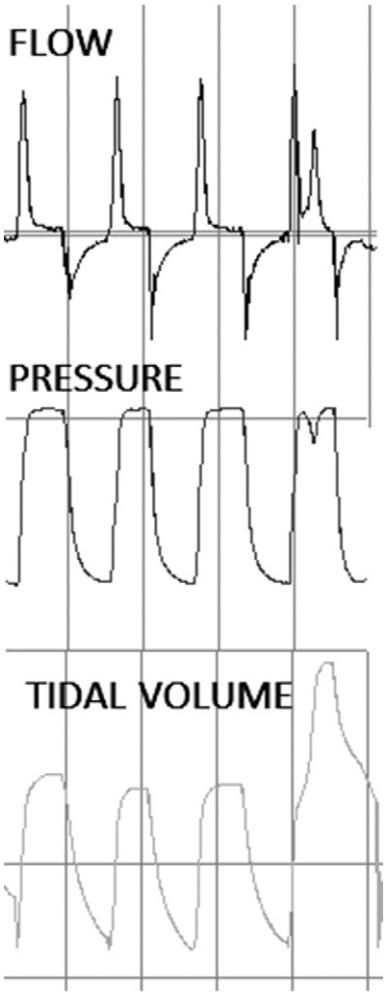

Fig. 1. Recording of the flow, pressure and tidal volume. An active inspiration is shown on the fourth inflation by the negative deflection in the inflation pressure trace and the double peak in the flow trace. The active inspiration is associated with an increased tidal volume.

Recordings were excluded from the analysis if:

(i) the infant had breathed prior to the onset of resuscitation
(ii) there was a large leak, defined as a difference between the inspiratory and expiratory tidal volumes of at least 30% likely making identification of the first active inflation inaccurate
(iii) the initial endotracheal tube had been misplaced and the infant required reintubation
(iv) there was no active inflation during the recording

2.5. Statistical analysis

Differences between infants whose recordings were and were not analysed were assessed for statistical significance using Mann Whitney *U* test or Chi squared test as appropriate. Strengths of correlations were assessed by calculating Pearson's correlation coefficients. Whether antenatal exposure was related to the time to the first inflation was assessed using the Mann Whitney *U* test. Data which were not normally distributed were log transformed as necessary for the analysis. Statistical analysis was carried out using SpSSC version 22, IBM, USA.