Physiological responses to facemask application in newborns immediately after birth

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ABSTRACT

Objective Application of a face mask may induce apnoea and bradycardia, possibly via the trigeminocardiac reflex (TCR). We aimed to describe rates of apnoea and bradycardia in term and late-preterm infants following facemask application during neonatal stabilisation and compare the effects of first facemask application with subsequent applications.

Design Subgroup analysis of a prospective, randomised trial comparing two face masks.

Setting Single-centre study in the delivery room

Patients Infants>34 weeks gestational age at birth

Methods Resuscitations were video recorded. Airway flow and pressure were measured using a flow sensor. The effect of first and subsequent facemask applications on spontaneously breathing infants were noted. When available, flow waveforms as well as heart rate (HR) were assessed 20 s before and 30 s after each facemask application.

Results In total, 128 facemask applications were evaluated. In eleven percent of facemask applications infants stopped breathing. The first application was associated with a higher rate of apnoea than subsequent applications (29% vs 8%, OR (95% CI)=4.76 (1.41–16.67), p=0.012). On aggregate, there was no change in median HR over time. In the interventions associated with apnoea, HR dropped by 38bpm [median (IQR) at time of facemask application: 134bpm (134–150) vs 96bpm (94–102) 20 s after application; p=0.25] and recovered within 30 s.

Conclusions Facemask applications in term and late-preterm infants during neonatal stabilisation are associated with apnoea and this effect is more pronounced after the first compared with subsequent applications. Healthcare providers should be aware of the TCR and vigilant when applying a face mask to newborn infants.

Trial registration number ACTRN12616000768493.

What is already known on this topic?

- Application of a face mask may trigger the trigeminocardiac reflex, leading to apnoea, bradycardia and hypotension through parasympathetic activity
- In preterm infants, approximately 50% stopped breathing after application of a face mask immediately after birth
- Facemask repositionings are recommended by neonatal resuscitation guidelines in case of suspected leak or obstruction

What this study adds?

- In term infants, ten percent of delivery room facemask applications are followed by a cessation of breathing.
- Infants who stop breathing show a clinically important decrease in heart rate (HR) after facemask application.
- There was no change in HR after facemask application except in the few observations associated with apnoea.

INTRODUCTION

Around five percent of newborn infants receive facemask ventilation during neonatal transition,[1–3] which may induce the trigeminocardiac reflex (TCR).[4–8] Application of a face mask may stimulate the afferent fibres of the three branches of the trigeminal nerve, triggering reflexes that ultimately lead to apnoea, bradycardia and hypotension.[8–10] Recently, it has been shown that fifty-four percent of preterm infants stopped breathing on application of a face mask immediately after birth, possibly due to the TCR.[7] However, it remains unclear whether the same effect can be observed in term and late-preterm infants during neonatal transition.

Mask leak and airway obstruction reduce the effectiveness of mask ventilation,[11] and facemask repositioning may be necessary to overcome these obstacles.[12] The TCR afferent pathway begins with rapidly adapting cutaneous mechanoreceptors and a prolonged or repeated application of a stimulus to these receptors is followed by a gradually diminishing response.[13 14] Thus, subsequent facemask applications may elicit a reduced TCR response compared with the first application.

We aimed to describe the incidence of apnoea, bradycardia and desaturations following facemask applications in term and late-preterm infants immediately after birth. We hypothesised that application of a face mask would be associated with an increased rate of apnoea, bradycardia and desaturations. We also hypothesised that facemask re-applications would induce a less pronounced reaction and that a novel mask, which uses a negative pressure to form a tight seal around the infant's mouth and nose, would elicit a greater response compared with a standard face mask.

METHODS

Population and intervention

This is a subgroup analysis of a previously published prospective, randomised clinical trial conducted at the Royal Women's Hospital, Melbourne.[15] The study was registered with the Australian and New Zealand Clinical Trial Registry. All parents provided written informed consent. The original trial compared the effect of two face masks – the suction mask (ResusiSure, LSR Healthcare, New South Wales, Australia) and a standard round silicone mask (Laerdal Silicone mask, Laerdal, Stavanger, Norway) – on mask leak in newborn infants>34 weeks gestation receiving facemask ventilation immediately after birth. All facemask applications, irrespective of the mode of respiratory support, were included in the analysis (ie, positive pressure ventilation or continuous positive airway pressure). The suction mask uses a negative pressure between the mask and the infant's face to form a seal.[15]

Measurements and data collection

A Neopuff Infant Resuscitator (Fisher & Paykel Healthcare, Auckland, New Zealand) was used to provide positive distending pressure. Airway flow and pressure were measured using a flow sensor with an accuracy of ±5% placed between the T-piece ventilation device and the face mask. Respiratory function parameters were recorded at 200 Hz using the New Life Box recording system (Advanced Life Diagnostics UG, Weener, Germany). Heart rate (HR) and oxygen saturation (SpO_2) were recorded using a Masimo pulse oximeter with a 2 s averaging time (Masimo Radical 7, Masimo Cooperation, Irvine California).

Resuscitations were video recorded from above providing a view of the infant's face and chest, and the operator's hands. Responses to first and all subsequent facemask applications were assessed. Any reapplication, irrespective of the time interval between facemask applications was counted as a separate application. When available, flow waveforms and breathing efforts were assessed continuously, when the face mask was applied, and pulse oximetry data were assessed every two seconds over 50 s. Recordings were made for twenty seconds before facemask application as previously published,[7] and 30 s after application to include all data until recovery to baseline in those infants who had a change in HR or SpO_2.

To evaluate spontaneous breathing, inspiratory and expiratory flow waveforms were assessed. If there was no flow data before facemask application (ie, all first applications and some re-applications), we used clinical data (ie, crying, visible chest excursions, vigorous spontaneous movements) to assess breathing.[7] Accuracy of clinical assessment was evaluated by comparing it to respiratory function monitor data when available. Applications were excluded if infants were already apnoeic before facemask application, or if there was no reliable flow data after application (see figure 1). Apnoea was defined as no spontaneous breathing for at least ten seconds after facemask application.[16]

Statistical analysis

Normally distributed data are presented as mean and SD whereas skewed data are presented as median and IQR. Differences in medians were analysed using the paired Wilcoxon test. Categorical dependent data were analysed by performing a logistic regression, accounting for within-subjects variance by using generalised estimating equations.[17] Changes in HR and SpO_2 over the pre-specified time frame were assessed using Friedman's test which tests the global difference in medians over time. In case of a significant global difference in HR or SpO_2 over time, post-hoc analyses were performed and corrected for multiple comparisons using the Bonferroni-Holm method. P-values<0.05 are considered statistically significant. Data were analysed using R statistics V.3.6.2.[18]

RESULTS

Population

In total, 41 of 45 randomised infants had video recordings available. Finally, facemask applications of 35 infants were included for further evaluation (see figure 1). Demographic and clinical characteristics are shown in table 1.

Overall, 223 facemask applications were noted during the first 10 min after birth (median 4 (IQR 2–6) applications per infant). In 156 applications, infants were breathing prior to application (70%). In 67 applications, the infant was apnoeic

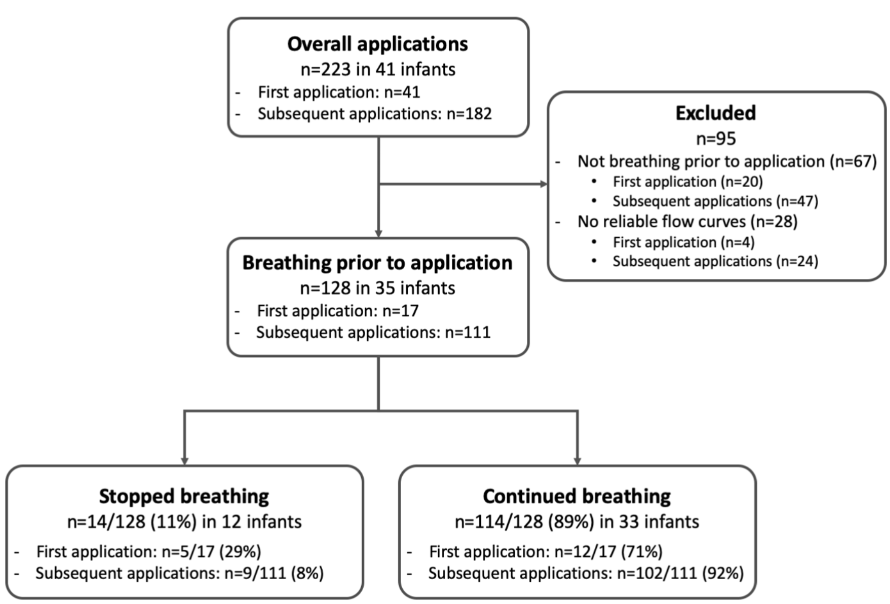

Figure 1 Flowchart of facemask applications and spontaneous breathing efforts before and after facemask application.

Table 1 Population demographics

	Population characteristics (N=35)
Gestational age (weeks+days)	38.3 (36.4–39.1)
Birth weight (g)	3060 (2829–3308)
Male, n (%)	24 (58)
Apgar at 1 min	3 (2–4)
Apgar at 5 min	7 (6–9)
Intubated in the DR, n (%)	3 (7)
Admission to NICU, n (%)	15 (36)

Where not otherwise specified, median and IQR are shown.
DR, delivery room; NICU, neonatal intensive care unit.

before application (30%). These 67 applications, as well as additional 28 applications with unreliable flow data, were excluded, leaving 128 applications for analysis (figure 1). In 53 of 128 applications (41%), data were based on clinical evaluation. Flow traces agreed with the clinical assessment of presence or absence of breathing when both were available (75 of 75 applications, 100%).

Effect on breathing

Overall, infants stopped breathing after 14 of 128 applications (11%, figure 1). These apnoeic events occurred in 12 different infants. Five of 17 first facemask applications were followed by an apnoea as opposed to 9 of 111 subsequent applications (29% vs 8%; OR 4.76, 95% CI 1.41 to 16.67, p=0.012). Figure 2 illustrates pressure, flow and tidal volume curves after facemask application in an infant that stopped breathing.

Effect on HR and SpO_2

Pulse oximetry data (preintervention and postintervention) were available in 51 of 128 facemask applications (40%). Overall, there was no statistically significant change in HR over time (χ^2=5.9, p=0.99; figure 3A). HR dropped by ≥10 beats/min after 10 of 51 facemask applications (20%) and 2 applications (4%) were followed by a bradycardia of <100 beats/min. HR rose by ≥10 beats/min after 6 applications (12%) and remained the same in 35 applications (69%).

Overall, there was no statistically significant change in SpO_2 over time (χ^2=19.0, p=0.80). SpO_2 dropped ≥10% after 2 of 51 applications (4%) and rose ≥10% after 8 applications (16%).

We had pulse oximetry data available for 3 of the 14 applications where infants stopped breathing. In these applications, there was a statistically significant change in HR over time (χ^2=38.9, p=0.037). On post hoc analysis, this difference was not attributable to a single comparison. However, HR dropped by 38 beats/min from a median of 134 beats/min (IQR 134–150) at the time of facemask application to 96 beats/min (IQR 94–102) 20 s after application (p=0.25). HR quickly recovered on stimulation and facemask ventilation (figure 3B). No infant received cardiac compressions.

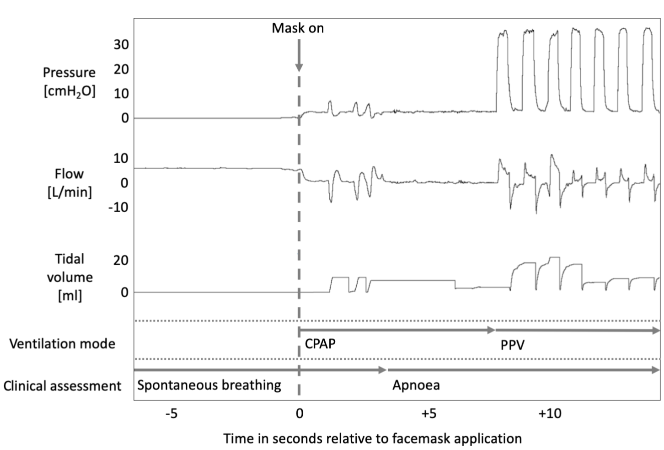

Figure 2 Example of pressure, flow and tidal volume curves of an infant that stopped breathing after facemask application. The vertical dashed line indicates the time when the face mask was applied. Clinically, the infant is breathing spontaneously until approximately 3 s after mask application, when the infant becomes apnoeic requiring the initiation of PPV. CPAP, continuous positive airway pressure; PPV, positive pressure ventilation.

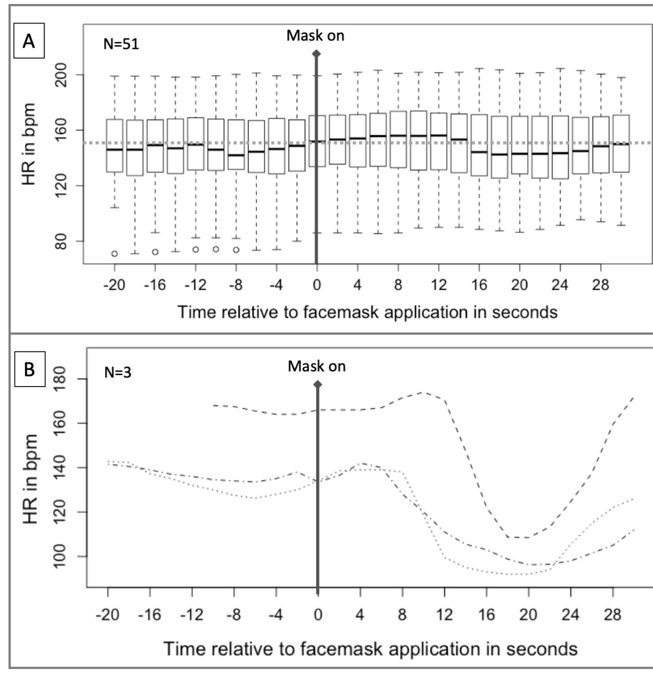

Figure 3 HR development in relation to facemask application. (A) All applications with available pulse oximetry data (N=51). (A) Boxes show medians and IQRs. (B) Individual progression of HR over time in applications where infants stopped breathing (N=3). The vertical thick grey line in both parts marks the time of facemask application. HR, heart rate.

Comparison between suction mask and conventional mask

There was no significant difference between suction mask and conventional mask with regard to apnoea, the number of decreases in HR≥10 beats/min and the number of decreases in SpO_2≥10% (table 2).

DISCUSSION

This is the first study evaluating the effect of facemask applications on respiratory effort, HR and SpO_2 in term and late-preterm infants immediately after birth. We have demonstrated that facemask applications in the delivery room were followed by a cessation of breathing in approximately 10% of infants. This was associated with a drop in HR in the small number with available data. Apnoea was more prevalent in response to the first facemask application than after subsequent applications. Contrary to our hypothesis, we did not observe any differences

Table 2 Comparison of physiological changes following facemask application using the suction mask and the conventional mask

	Overall	Suction mask	Conventional mask	OR (95% CI)	P value
Stopped breathing, n (%)	14/128 (11)	5/52 (10)	9/76 (12)	0.79 (0.19 to 3.25)	0.75
HR drop ≥10 beats/min, n (%)	10/51 (20)	5/15 (33)	5/36 (14)	3.1 (0.97 to 9.91)	0.06
SpO_2 drop ≥10%, n (%)	2/51 (4)	1/15 (7)	1/36 (3)	2.5 (0.08 to 75.7)	0.60

The number of infants varies due to availability of pulse oximetry data.
HR, heart rate; SpO_2, oxygen saturation.

in rates of apnoea and bradycardia between the two face masks studied.

Effective ventilation is key to successful neonatal resuscitation.[19 20] However, in some instances, removal of the face mask can improve independent respiratory efforts, potentially by reducing the deleterious effects of the TCR.[8 9] A recent study showed that approximately 50% of preterm infants became apnoeic on the first facemask application after birth.[7] Our results suggest that the effect on apnoea is less pronounced in term infants. There are several potential explanations for this difference. Sensory input into the central nervous system and autonomic output mature through gestation and central control mechanisms are augmented.[21 22] We speculate that the higher level of arousal in term infants could over-ride some of the inhibitory effects of the TCR. In the previous study, 70% of preterm infants who stopped breathing received sustained inflations. The high pressure during a sustained inflation may initiate a TCR response that is independent of or additional to the facemask application.[23] We included a high proportion of subsequent facemask applications and found that the effect on apnoea was diminished when compared with the first application.

Mask leak and airway obstruction are potential impediments to adequate ventilation, and repositioning of the face mask is recommended.[12 24] In our study, approximately 10% of reapplications were followed by an apnoea. Thus, it remains important to continuously assess breathing efforts after any facemask application.

We observed a median of four facemask applications per infant. It was not possible to ascertain the reason for reapplication using video recordings, but facemask removal may have been unintentional on some occasions (eg, when the physician was focused on the monitors). The high number of repositionings demonstrate how often positive distending pressure is lost during facemask ventilation, potentially contributing to cardiorespiratory instability during neonatal stabilisation.

There were no differences between a suction mask and a conventional mask with regard to apnoea or bradycardia, and thus, our hypothesis was not supported. Since mucosal stimulation elicits the TCR,[25] we speculate that warm, humidified gases may reduce the incidence of TCR-induced apnoea and bradycardia, but further studies are needed.

We showed that 20% of facemask applications were followed by a reduction in HR of ≥10 beats/min. The subgroup of infants who stopped breathing after facemask application had a more pronounced drop in HR. As these infants were breathing regularly before application, it seems likely that this effect may correspond to a TCR-induced reflex bradycardia, which may have been compounded by an evolving hypoxia. Only 4% of applications were followed by a bradycardia of <100 beats/min, which was transient in all cases, and infants recovered on stimulation and/or the initiation of mask ventilation within 10 s after the nadir in HR. Clinicians should be aware of TCR-induced apnoea and/or bradycardia when applying a face mask to a breathing infant.

This study has several limitations. In a retrospective, observational study, it is difficult to disentangle random or chance effects from true results. However, in a small number of applications, infants stopped breathing and we noted a significant drop in HR of ≥30 beats/min, possibly due to TCR activation. Additionally, our study is limited by the small sample size, which may explain the lack of difference between suction mask and conventional mask. Lastly, we evaluated video recordings where it is difficult to determine clinical actions and reactions. For most facemask applications, we had flow curves available, thus guaranteeing accurate and unbiased data on the incidence of apnoea. In our clinical assessment, we included visibility of chest excursions and distinct spontaneous movements, which do not necessarily imply adequate respirations and are prone to misjudgement. However, when both were available, there was complete agreement between clinical assessment and respiratory function monitoring in all cases, indicating a low risk of bias in determining the primary outcome.

Finally, there are alternate explanations for apnoea during newborn stabilisation: airway obstruction from secretions or malposition of the head and neck, hypoxia from any cause and placental transfer of maternal medicine. While apnoea due to the TCR has been described and may be responsible for apnoeic events during transition in late preterm and term infants, our study was not designed to prove a causal relationship.

CONCLUSION

Approximately 30% of initial facemask applications and 10% of all subsequent applications in term and late-preterm newly born infants are associated with a cessation of breathing and subsequent bradycardia. This may be caused by the TCR. Our findings suggest that the reflex is less prominent in term infants than recently described for preterm infants. Healthcare providers should be aware of this phenomenon as a potential cause of apnoea and bradycardia during neonatal stabilisation and should be watchful when applying a face mask to newly born infants in the delivery room, especially to infants who are breathing.

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Contributors All authors were involved in planning, conducting and reporting of the work. VDG watched the videos, performed data analyses and wrote the first version of the manuscript. CMR, EOC, COFK, SBH, PGD and LS were involved in data interpretation, as well as manuscript writing. LS supervised the project. All authors approved the final version of the manuscript.

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Competing interests None declared.

Patient consent for publication Not required.

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