T-Piece Resuscitation: Neonates and Infants

Clinical Paper Summaries

Fisher & Paykel HEALTHCARE

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BACKGROUND

The transition from fetal to neonatal life requires a coordinated sequence of anatomic and physiologic events that enable the change from placental gas exchange to pulmonary respiration. The respiratory transition at birth involves the clearance of fetal lung fluid, the initiation of breathing, and ventilation of the distal airspaces. Adequate lung ventilation is critical for establishing pulmonary gas exchange, as well as initiating the cardiovascular changes that occur at birth (Hillman et al. 2012; Hooper et al. 2016).

It is estimated that about 10% of all newborns are delivered with absent or poor respiratory effort and need some level of support to achieve cardiopulmonary stability. Perinatal asphyxia occurs when an infant doesn't receive enough oxygen before, during, or just after birth (Ersdal et al. 2012). Severe perinatal asphyxia (causing death or severe neurological impairment) remains a worldwide problem and is estimated to occur at a rate of about 1/1000 live births in resource-rich countries and 5–10/1000 live births in resource-poor countries (McGuire et al. 2007).

LUNG ADAPTATIONS DURING THE TRANSITION

Adequate development of the fetal lung is necessary for gas exchange to occur at birth. As birth approaches, fetal lung fluid secretion stops and lung fluid volume decreases. Also, pulmonary surfactant, a substance essential for stabilizing the lung structure and function, is secreted into the fetal lung fluid. During respiratory transition, neonates inflate their lungs at birth by generating large negative-pressure breaths, which pull the lung fluid from the airways into the distal airspaces. Failure to adequately clear the airways of lung liquid at birth is a major cause of neonatal morbidity and mortality, particularly in very preterm infants (Hillman et al. 2012).

THE NEED FOR RESPIRATORY SUPPORT DURING TRANSITION

Most newborns do not require any intervention to make the necessary transitional changes (Wyllie et al. 2015). However, many preterm or asphyxiated-term infants do not have adequate spontaneous respirations at birth and require assistance to clear lung fluid, ventilate their lungs, and establish a consistent functional residual capacity (FRC). FRC is the volume of air that remains in the lungs following a typical expiratory phase and is important for keeping the lungs open post exhalation and for ensuring adequate pulmonary gas exchange (te Pas et al. 2009).

Infants born prematurely often have structurally immature lungs with reduced potential lung gas volume relative to body weight and metabolic needs, compared to term infants. Furthermore, the clearance of fetal lung fluid may be delayed in the premature infant as secretion of lung fluid may not have ceased prior to and after delivery. In addition, in the premature lung, the quality and the amount of surfactant that can be secreted in response to birth may be low (Hillman et al. 2012). Therefore, at birth, the immature lungs of premature infants can be difficult to ventilate as they are fluid filled, and the level of surfactant may be insufficient to decrease surface tension and maintain FRC (Hillman et al. 2012).

Respiratory support in the delivery room (DR) commonly involves the application of positive pressure ventilation (PPV). PPV can be applied either noninvasively (via a face mask) or following intubation of the trachea (Hillman et al. 2012).

RESUSCITATION IN PRACTICE: WHAT THE GUIDELINES SAY

The algorithm contained in the latest US guidelines, the 2015 International Consensus on Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care Science With Treatment Recommendations (CoSTR), outlines the steps necessary during neonatal resuscitation (Wyllie et al. 2015). Heart rate and respiration are two main vital signs that are used to identify the need for an intervention and assess any response to the interventions. It is recommended that progression through the steps of the algorithm occur only after successful completion of each step, the most critical being effective ventilation (Wyllie et al. 2015). PPV can be provided to assist breathing in neonates with apnea or bradycardia while other interventions (continuous positive airway pressure [CPAP] or oxygen) may be appropriate if the neonate has labored breathing or low oxygen saturation (Weiner et al. 2016).

KEY POINTS

- The neonatal respiratory transition involves the clearance of fetal lung fluid, the initiation of breathing, and ventilation of the distal airspaces.
- The immature lungs of premature infants can be difficult to ventilate as they are fluid filled, and the level of surfactant may be insufficient to decrease surface tension and maintain FRC.
- PPV is an appropriate intervention for preterm or asphyxiated- term infants who do not have adequate spontaneous respirations at birth and require respiratory support.
- The provision of effective ventilation is the most critical step in neonatal resuscitation.

BACKGROUND

Adequate ventilation of the lungs and establishment of a functional residual capacity (FRC) are crucial for successful neonatal resuscitation (Hillman et al. 2012). In the delivery room (DR), manual respiratory support is commonly provided with a self-inflating bag (SIB), a flow-inflating bag (FIB), or a T-piece resuscitator (TPR) (Wyckoff et al. 2015). The TPR can be used during neonatal resuscitation to provide consistent and controlled delivery of peak inspiratory pressure (PIP) and positive end-expiratory pressure (PEEP). PIP is the maximum inspiratory pressure required to improve oxygenation without causing adverse effects and PEEP is the residual pressure maintained at the end of expiration (Bennet et al. 2005).

T-PIECE RESUSITATOR VERSUS OTHER MECHANICAL VENTILATION DEVICES

A multi-center, randomized controlled trial (RCT) comparing the use of an SIB (with or without a PEEP valve) to a TPR in neonates of ≥ 26 weeks gestational age (GA) found that the use of a TPR significantly decreased the intubation rate (17% vs. 26%; p = 0.002) and the maximum PIP applied, as well as the variability of the PIP (26 ± 1.9 cmH_2O vs. 28 ± 4.9 cmH_2O) (Szyld et al. 2014).

A qualitative review comparing the TPR to the SIB and the FIB found that resuscitation using a TPR had several advantages, including the provision of close-to-target PIP and PEEP, more consistent tidal volume (V_t), and the ability to provide prolonged inflation breaths (Hawkes et al. 2012).

THE IMPORTANCE OF OPERATOR EXPERIENCE AND TRAINING

Operator training is necessary when using any neonatal resuscitation device and studies have shown that appropriately trained operators are able to achieve more consistent delivery of predetermined PIP and PEEP pressures with a TPR when compared to an SIB or FIB, independent of their level of professional experience (Hawkes et al. 2012). In two bench/laboratory studies examining V_t and PIP during simulated resuscitation, Roehr et al. showed that operator training level and device-specific experience had a significant impact on PIP and V_t when using an SIB for manual ventilation. Also, for operators with no specific training in manual ventilation, the use of a TPR was advised for the control of excessive PIP and V_t (Roehr et al. 2010).

A comparative study in which trained healthcare professionals were asked to provide positive pressure ventilation (PPV) to an intubated neonatal mannequin found that accurate, reliable, and reproducible manual ventilation in infants of very low birthweight can be achieved using an anesthetic bag with manometer or the Neopuff™ TPR device (Fisher & Paykel Healthcare, Auckland, New Zealand), independent of training or specialty. It was concluded that self-inflating mechanical ventilation devices without a manometer should not be considered as first choice for the manual ventilation of infants with a very low birthweight due to the high PIP and minimal PEEP that is associated with their use (Hussey et al. 2004).

THE IMPORTANCE OF MASK SIZE

It can be challenging to maintain a face mask seal while delivering PPV. Therefore, careful consideration needs to be given to mask size, fit, and hold as a good seal with minimized leak is important for establishing effective ventilation.

O'Shea et al. have reported that the smallest size of some brands of mask could be too large for many preterm infants. In particular, masks of 35 mm diameter were found to be suitable for infants of < 29 weeks post-menstrual age or 1000 g and masks of 42 mm diameter suitable for infants of 27–33 weeks postmenstrual age or 750–2500 g (O'Shea et al. 2016).

CONTROLLED INFLATION BREATHS

A TPR can be used to deliver controlled inflation breaths. Longer inflation breaths, also known as sustained inflation (SI), has been shown to facilitate the establishment of FRC to a greater extent than intermittent positive pressure ventilation (IPPV) (Vyas et al. 1981; te Pas et al. 2016). However, the clinical data on safety and efficacy of this resuscitation strategy is not conclusive.

A number of RCTs have investigated the impact that longer inflation breaths delivered via a TPR have on outcomes in neonates. A meta-analysis comparing the effects of SI with those of IPPV on the birth outcomes of preterm infants showed that SI reduced the need for mechanical ventilation during the first 72 hours after birth (relative risk [RR] 0.87; 95% CI 0.77, 0.97). However, SI did not improve the rate of bronchopulmonary dysplasia (BPD) or death. (Schmolzer et al. 2015).

An RCT comparing the efficacy and safety of SI (using a TPR) compared to conventional bag/mask inflation for the resuscitation of preterm infants found that SI was associated with a significantly higher success rate than conventional bag/mask inflation (75.4% vs. 54.5%; p = 0.017). In this trial, success was defined as not requiring ventilatory support, need for exclusive nasal continuous positive airway pressure, or need for intubation beyond the first 72 hours. The rates of air leak and BPD, however, were not significantly different between the two groups (El-Chimi et al. 2016).

The Sustained Aeration of Infant Lungs (SAIL) trial was the first large, multi-center RCT designed to determine whether initial SI with PEEP was superior to standard practice (initial IPPV with PEEP) in extremely preterm infants. This trial, conducted in 18 neonatal intensive care units (NICU) across nine countries, enrolled preterm infants with a GA of 23–26 weeks requiring resuscitation at birth due to inadequate respiratory effort or bradycardia. The results of this trial showed an unexpected mortality rate of 7.4% in the SI group vs. 1.4% in the standard resuscitation group (p = 0.002) during the first 48 hours of life. The very low probability of benefit (with respect to the primary outcome) if enrolment had continued led to the early closure of the trial. It was concluded that, in extremely preterm infants requiring resuscitation at birth, a ventilation strategy involving SI, compared with standard IPPV, did not reduce the risk of BPD or death at 36 weeks postmenstrual age (primary endpoint). The early deaths were predominantly in the smallest (23–24 weeks GA), most vulnerable infants. An implication of this finding is that caution should always be exercised in extrapolating findings from a more mature population to infants at the borderline of viability, who may respond differently or be more vulnerable to adverse effects of an intervention (Kirpalani et al. 2019a and b).

The 2015 American Heart Association Neonatal Resuscitation Guidelines Update states that there is insufficient data regarding short- and long-term safety and the most appropriate duration and pressure of inflation, to support routine application of SI of > 5 seconds duration to the transitioning newborn (Wyckoff et al. 2015).

KEY POINTS

- Administration of PPV, using either a TPR, FIB, or SIB, is recommended in the guidelines for providing resuscitation to both preterm and term infants who are apneic.
- A TPR provides consistent and controlled delivery of PIP, PEEP, and V_t, and can be used to provide controlled inflation pressures.
- TPRs can be reliably and consistently used by healthcare professionals provided the size, fit, and hold of the mask are appropriate.
- Although there is a sound physiologic basis for the use of SI breaths, the clinical data on safety and efficacy of this approach as a resuscitation strategy is inconclusive and is therefore not currently recommended. The implications of the SAIL trial continue to be debated by clinical experts.

THERMOREGULATION IN THE NEWBORN

Despite advances in neonatal care, maintaining a newborn's temperature within the optimum range remains a challenge. Guidance on thermoregulatory techniques such as skin-to-skin contact, and drying and wrapping, has been an initial and integral part of newborn life support algorithms. The World Health Organization (WHO) advocates that neonatal body temperature be maintained at 36.5–37.5 °C (normothermia), and it classifies 36.0–36.4 °C as mild hypothermia, 32.0–35.9 °C as moderate hypothermia, and < 32.0 °C as severe hypothermia. The maintenance of a normal body temperature in the neonate is essential for survival, with hypothermia or hyperthermia being associated with an increased risk of neonatal mortality and morbidity in both preterm and term infants (Laptook et al. 2007; Trevisanuto et al. 2018).

There are a few different mechanisms by which heat loss may occur and therefore several interventions must be considered when trying to achieve temperature maintenance in the newborn. These interventions in relation to the mechanism of heat loss are shown in the table below (Trevisanuto et al. 2018).

Table 1. Delivery-room interventions that can help to prevent neonatal hypothermia. Adapted from Trevisanuto et al. 2018.

Mechanism of heat loss	Intervention
Evaporation can occur during birth from moisture on skin, and as a result of wet clothes and linen.	Plastic wrap, cap The use of heated and humidified gas during resuscitation
Conduction occurs when the infant comes in contact with cold objects or surfaces.	Skin-to-skin contact Pre-warmed resuscitation bed and linen Removal of wet linen Exothermic mattress Hat/cap
Radiation heat loss occurs when the infant is near colder surfaces.	Radiant warmer
Convection occurs when drafts come from open doors or air-conditioning.	High environmental temperature Reduce air draft by closing door/window Plastic wrap, cap The use of heated and humidified gas during resuscitation

RATIONALE FOR DELIVERING HEATED AND HUMIDIFIED GAS DURING RESUSCITATION

Humidified resuscitation is a method of delivering warm, humidified gas to an infant during ventilatory support at birth. In general, delivering heated and humidified gas (HHG) has a range of physiological and clinical benefits including the preservation of mucociliary function, prevention of airway drying, clearing of retained secretions, and the prevention of hypothermia (Dawson et al. 2014; Meyer et al. 2018). While delivering HHG is a well-accepted approach for long-term respiratory support in specialized care units, heating and humidifying gas during transient therapies such as during resuscitation in the delivery room (DR) is less prevalent with cold, dry gas commonly used during stabilization after birth and transport to the neonatal intensive care unit (NICU).

THE IMPORTANCE OF HUMIDIFICATION

Normally, as air enters the airway it gains heat and moisture until it is at equilibrium with the airway mucosa (37 °C, 100% Relative Humidity). It has been calculated that the energy used to heat and humidify dry resuscitation gases to these levels is about 40 kJ/kg/day (85% of which is used in humidification) (Sottiaux et al. 2006). Also, as oxygen consumption increases with a greater temperature gradient between the infant and the environment, using unconditioned gas would place additional stress on infants (Dawson et al. 2014). Studies have shown that the use of cold, dry gas in ventilated infants for just 5 minutes results in a significant decrease in both pulmonary compliance and conductance (Greenspan et al. 1991).

CLINICAL DATA AVAILABLE FOR THE BENEFITS OF USING HHG DURING RESUSCITATION

The results of two key RCTs have been analyzed in a meta-analysis published by Meyer et al. in 2018. In the first study, infants < 32 weeks gestational age (GA) requiring respiratory support at birth were randomized to receive medical gas which was either heated to 37 °C and humidified or cold and dry (unconditioned gas) directly from the supply source. The study was designed to detect an improvement in the number of patients whose admission temperature was in the normothermic range (36.5–37.5 °C) (Meyer et al. 2015). The second study was a multi-center trial that enrolled preterm infants < 30 weeks GA. A similar protocol to the first study was employed and the study was designed to detect a reduction in patients with admission temperature below 36.5 °C (McGrory et al. 2018). In both studies, heating and humidification were achieved by adding 30–50 ml water to the humidifier chamber (MR850™ Heated Humidifier, Fisher & Paykel Healthcare, Auckland, New Zealand).

The key conclusion of the meta-analysis was that the use of HHG, compared with unconditioned gas, significantly reduced admission hypothermia. In a subset analysis, preterm infants with a GA of < 28 weeks had significantly less admission hypothermia when treated with HHG, compared to no gas conditioning. Measures of respiratory outcomes (intubation in DR, use of surfactant, pneumothorax, days of respiratory support, chronic lung disease) or other neonatal outcomes were not significantly different between the two treatment groups. However, neither study was designed to assess respiratory and other neonatal outcomes.

Similar outcomes to those reported in the two recent RCTs have previously been reported in an observational study that also included preterm infants of < 32 weeks GA. In that study, moderate hypothermia (< 36 °C) was less frequent and admission normothermia was increased in infants receiving HHG during stabilization at birth. In addition, there was no significant increase in admission hyperthermia (te Pas et al. 2010).

CURRENT GUIDELINE RECOMMENDATIONS

The 2015 International Consensus on Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care Science with Treatment Recommendations (CoSTR) strongly recommend that the temperature of newly born non-asphyxiated infants be maintained between 36.5 and 37.5 °C after birth through admission and stabilization. It is also recommended that hyperthermia (> 38.0 °C) be avoided due to the potential associated risks. However, current international neonatal resuscitation guidelines do not provide recommendations on conditioning inspired gas at delivery.

Future larger studies that are appropriately designed are needed to inform the range of clinical benefits of using HHG in the DR, the feasibility of this approach, and short- and long-term effects associated with this strategy (Wyllie et al. 2015).

KEY POINTS

- In neonates, the maintenance of body temperature within the range 36.5–37.5 °C is essential, with hypothermia or hyperthermia being associated with an increased risk of neonatal mortality and morbidity in both preterm and term infants.
- Thermoregulation, the ability to produce heat and maintain a normal body temperature, is a vital metabolic function and a continuous challenge for the newborn.
- There is strong evidence from RCTs that the use of HHG during the early stabilization and transport of preterm infants improves NICU admission temperatures.

AIM

To investigate the effect of operator training in neonatal manual ventilation on the level of peak inspiratory pressure (PIP) and tidal volume (V_t) during simulated neonatal resuscitation.

METHOD

Study population and design: Eighty-four healthcare professionals (10 pediatricians; 22 anesthetist; 30 neonatal nurses; 22 midwives) were enrolled in this prospective cross-over trial. Participants were defined by four levels of training: level 0 = no previous training; level 1 = training on manual ventilation in neonates; level 2 = level 1 plus history of tutorial on lung protective management; level 3 = level 2 plus specific manometer training.

Study setup: Neonatal resuscitation was simulated using a leak-free neonatal mannequin resembling an infant with very low birthweight (VLBW; birthweight < 1500 g), equivalent to a 1 kg infant lung with a compliance of 0.2 mL kPa–1.

Devices tested: Two different manual resuscitation devices were used – a self-inflating bag (SIB) consisting of a new 240 mL Laerdal R-bag (Laerdal) with a new AmbuR-10-PEEP-valve [Ambu] set at 5 cmH_2O; and a T-piece resuscitator (TPR, Neopuff™; Fisher & Paykel Healthcare) with the positive end-expiratory pressure (PEEP) set at 5 cmH_2O. A brief tutorial on the theoretical background and means of operation of the devices prior to testing was conducted to ensure that each participant had an equal understanding of the use of both devices.

Study protocol: Wall-mounted medical air provided a continuous gas flow of 8 L/min and participants were asked to manually ventilate to a target PIP of 20 cmH_2O and a PEEP of 5 cmH_2O with a rate of 60 breaths/min. Applied PIP and the resulting V_t were measured using a pneumotachograph (CO_2SMO+R; Novametrix Inc.).

RESULTS

- Operator training significantly affected the level of PIP and V_t when using a SIB for manual ventilation but not when using a TPR (see table below).
- The level of operator training also had a significant effect on inspiratory time when using a SIB (p = 0.048).

Table 2: Comparison of performance by individual training level.

	Training level	SIB Median (IQR)	P value	TPR Median (IQR)	P value
PIP (cmH_2O)	0	34.5 (8.0)	<0.001*	19.7 (0.43)	0.556
	1	32.9 (12.8)		19.6 (0.5)	
	2	24.7 (15.3)		19.6 (0.5)	
	3	18.3 (11.8)		19.7 (0.5)	
V_t (mL)	0	7.3 (8.0)	<0.001*	3.5 (0.8)	0.661
	1	6.4 (2.7)		3.5 (0.5)	
	2	4.8 (2.2)		3.4 (0.3)	
	3	3.8 (2.3)		3.5 (0.3)	

IQR = interquartile range; PIP = peak inspiratory pressure; SIB = self-inflating bag; TPR = T-piece resuscitator; V_t = tidal volume.

DISCUSSION

VLBW infants often require non-invasive respiratory support. However, excessive PIP and high V_t during manual ventilation can cause volutrauma and barotrauma in the neonatal lung.

In order to reduce neonatal lung injury, the avoidance of high PIP and V_t is essential. The International Liaison Committee on Resuscitation (ILCOR) and European Resuscitation Council (ERC) guidelines equally recognize SIBs and TPRs for manual neonatal resuscitation. While SIBs are the most commonly used device in neonatal resuscitation units worldwide, most are used without pressure manometers or appropriate pressure control.

Data from this study indicates that the level and consistency of delivered PIP and V_t depends on the resuscitation device and the level of operator training. There was large inter-subject variability in levels of applied PIP and V_t with the SIB for all training levels. However, the higher the operator's level of training, the better the adherence to the targeted PIP. In comparison, the use of a TPR provided consistent delivery of a defined PIP and V_t in a simulated neonatal resuscitation scenario, irrespective of operator training level.

KEY POINTS

- PIP and V_t are strongly influenced by the choice of manual ventilation device used during simulated neonatal resuscitation.
- TPRs provide more reliable and constant PIP and V_t than an SIB, irrespective of prior experience or level of profession of the operator.
- The higher the operator's level of training in manual neonatal resuscitation, the better the adherence to the targeted PIP and V_t when using a SIB. However, larger inter-individual variation is still a problem at all training levels.

S2. Summary: T-piece or self-inflating bag for positive pressure ventilation during delivery-room resuscitation.

A Thakur, S Saluja, M Modi, N Kler, P Garg, A Soni, A Kaur, S Chetri.
Resuscitation 2015; 90:21–24

AIM

To compare the duration of positive pressure ventilation (PPV) during delivery room (DR) resuscitation in neonates resuscitated with a self-inflating bag (SIB) or a T-piece resuscitator (TPR).

METHOD

Study design and setting: This randomized controlled trial (RCT) was conducted in the DR and neonatal intensive care unit (NICU) of a tertiary care centre in northern India.

Patient group: A total of 90 neonates of > 26 weeks gestational age (GA) requiring PPV at birth were eligible for inclusion.

Treatment arms: The eligible neonates were randomized at birth to treatment with a SIB without a positive end-expiratory pressure (PEEP) valve assembly (Laerdal Silicone Resuscitator, Laerdal, Stavanger, Norway) or a TPR (Neopuff™, Fisher & Paykel Healthcare, Auckland, New Zealand). With the TPR, the initial peak inspiratory pressure (PIP) and PEEP were set at 20 cmH_2O and 5 cmH_2O, respectively. In both the groups, PPV was delivered at the rate of 40–60 breaths per minute, and the inflation pressure was adjusted to achieve a visible chest rise. PPV was started with room air and oxygen was used according to recommended guidelines.

Outcome measures: The primary outcome was duration of PPV. Secondary outcomes were DR intubation rate, incidence of respiratory distress, need for surfactant replacement therapy, need for mechanical ventilation during the first 48 hrs and its duration, and mortality during NICU stay.

RESULTS AND DISCUSSION

Baseline characteristics of neonates enrolled in each of the study arms were comparable. The median duration of PPV in the SIB and TPR groups was 60 and 30 seconds, respectively ($p < 0.001$). Also, a higher proportion of neonates in the TPR group when compared to the SIB group could be resuscitated with room air only (72.5% vs. 38%, $p = 0.001$). More neonates resuscitated with SIB required DR intubation when compared to those resuscitated with a TPR (34% vs. 15%, $p = 0.04$). Fewer neonates < 34 weeks of gestational age (GA) receiving TPR required invasive ventilation (31.6% vs. 77.8%, $p = 0.008$).

The proportion of neonates who received surfactant or invasive ventilation was comparable between the groups and there was no significant difference in the duration of mechanical ventilation and mortality during NICU stay.

- Baseline characteristics of neonates in each study group.

Study group (n)	Mean birthweight (g)	GA (weeks)
TPR (40)	2065	34.3
SIB (50)	2264	35.1

- Neonatal outcomes during delivery room resuscitation and NICU stay are summarized in Table 3.

Table 3: Key outcomes of the study

Study outcomes/Variables	All neonates			Neonates < 34 weeks		
	TPR (n=40)	SIB (n=50)	p value	TPR (n=19)	SIB (n=18)	P value
Median duration of PPV, s	30	60	<0.001*	30	60	0.02
Resuscitation with room air (%)	73	38	0.001*	63	28	0.04
Intubation in DR (%)	15	34	0.04	26	67	0.01
NICU admission (%)	68	64	0.76	100	100	1.0
Invasive ventilation (%)	20	34	0.16	32	78	0.008
Duration of mechanical ventilation, h	42	40	0.88	42	44	0.47
Surfactant administration (%)	20	20	1.0	32	50	0.25
Mortality (%)	7.5	6	0.94	16	17	0.99

The ability to apply PEEP with the TPR may explain these outcomes, given that the use of PEEP has been associated with the establishment and maintenance of functional residual capacity (FRC) and improved oxygenation. Limitations of the current study included the unblinded, quasi-randomized trial design. In addition, PIP, achieved PEEP, and inflation time were not measured and a pulse oximeter was not used to measure oxygen saturation during resuscitation.

Intubation rates

Study	Mean GA (wks.)	TPR	SIB	P value
Dawson et al. 2011	27	53%	37%	0.13
Szyld et al. 2014	36	17%	26%	0.002*

Results from similar studies

Two other similar randomized trials (Dawson et al. 2011; Szyld et al. 2014) have also been conducted; however, neither of them reported on the impact of the devices on the duration of PPV. Szyld et al. reported significantly higher intubation rates with use of the SIB compared to the TPR. However, Dawson et al. did not observe any between-group difference in intubation rates when these two devices were used in extremely preterm neonates. The underdeveloped lungs, the highly compliant chest wall, and poor respiratory drive of extremely preterm neonates may account for the lack of difference in DR intubation rates in the study.

KEY POINTS

- Use of a TPR, compared to a SIB, decreased the duration of PPV.
- Fewer neonates required DR intubation and more neonates were successfully resuscitated with room air with the TPR than with the SIB.
- TPR may reduce the need for invasive ventilation in preterm neonates of < 34 weeks GA.

S3. Measurements from preterm infants to guide face mask size.

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AIM

To measure facial dimensions in preterm infants at birth and over the first weeks of life and compare these with the diameter of commonly available round masks used to deliver positive pressure ventilation (PPV).

METHOD

Patient group: Preterm infants with a gestational age (GA) < 34 weeks admitted to the neonatal intensive and special care unit were eligible for inclusion.

Study method: Each infant was photographed within 72 hours of birth and weekly until they reached 33 weeks and 6 days' postmenstrual age (PMA) or until discharge/transfer. Photographs were taken when the infant was lying down with their head and jaw in neutral positions (as they would be to receive mask PPV). The distance from the nasofrontal groove to the mental protuberance was measured. Measurements were compared against three round masks: Laerdal 0/0 (Laerdal), diameter 50 mm; and Infant Resuscitation Masks (Fisher & Paykel Healthcare), diameter 42 mm (small size) and 35 mm (extra-small size).

RESULTS

A total of 107 infants with a GA of 24–33 weeks were enrolled in the study between September 2011 and September 2013. Photographs were used to make 347 facial measurements (median 3 per infant). Initial facial measurements are shown in table 4. There was no difference in measurements between males and females, or when small for gestational age infants were excluded. Initial measurements for each GA were similar to serial measurements based on PMA, which indicates that postnatal facial growth in preterm infants occurs at a similar rate to antenatal facial growth.

Table 4 : Initial measurements presented for each week of gestation for the whole study population.

Gestational age, completed weeks	Initial measurement, mm (Values are mean ± standard deviation)
24	32 ± 2
25	35 ± 3
26	36 ± 3
27	37± 3
28	38 ± 4
29	40 ± 4
30	41 ± 2
31	39 ± 4
32	43 ± 4
33	42 ± 5

KEY POINTS

- A round mask with an external diameter of 50 mm may be too large for preterm infants of < 34 weeks GA (Figure 1).
- A round mask with an external diameter of 42 mm is suitable for preterm infants of 29–33 weeks PMA or weighing 1000–2500 g.
- A round mask with an external diameter of 35 mm is suitable for preterm infants of < 29 weeks PMA or weighing < 1000 g (Figure 1).

35 mm mask
Fisher & Paykel Healthcare size:
Extra Small

50 mm mask
Laerdal size:
0/0

Figure 1: A comparison of commonly used face masks. A re-creation of study findings using the Laerdal doll (25-week-old PMA infant; birthweight 750g).

AIM

To determine the magnitude of the reduction in admission hypothermia and examine neonatal outcomes (including mortality) after treatment of preterm infants with heated humidified gas (HHG) compared to cold, dry gas immediately after birth and during transport to the neonatal intensive care unit (NICU).

METHOD

This meta-analysis involved a literature search conducted in accordance with the standard methods of the Cochrane Neonatal Work Group to identify randomized controlled trials (RCT) that compared the use of HHG and cold, dry gas during the stabilization of preterm infants (< 37 weeks gestational age [GA]) immediately after birth and during transport to the NICU. The GRADE approach (see Glossary) was used to determine the quality of evidence, and the risk of bias was assessed for the included studies. The primary outcome was hypothermia (< 36.5 °C) at the time of admission into the NICU.

RESULTS

- The following two RCTs were included in the meta-analysis:

	Meyer et al. 2015	McGrory et al. 2018
Study site	New Zealand and The Netherlands	Melbourne, Australia
GA cut-off (weeks)	< 32	< 30
Temperature measurement	Axilla	Rectal
Study design	Infants were randomized to receive medical gas which was either heated to 37 °C and humidified (MR850™ Heated Humidifier, Fisher & Paykel Healthcare, Auckland, New Zealand) or unconditioned gas direct from the supply (wall or bottle). CPAP was given with a T-piece resuscitator (Neopuff™, Fisher & Paykel Healthcare, Auckland, New Zealand).	
Other measures used to prevent hypothermia	Heated delivery rooms (DR), radiant warmers, body wrap, head covering	

- The use of HHG, compared with no heating or humidification, reduced admission hypothermia and increased admission normothermia (see table below). The GRADE quality of evidence for these outcomes was high.
- Preterm infants with a GA of < 28 weeks had significantly less admission hypothermia when stabilized with HHG, compared with no heating or humidification of the gas.
- Measures of respiratory outcomes (intubation in DR, use of surfactant, pneumothorax, days of respiratory support, chronic lung disease) or neonatal outcomes were not significantly different between the two treatment groups.
- There were no significant adverse events and no increase in admission hyperthermia (> 37.5 °C).

Table 5. Heating and humidification compared with no heating and humidification (control) of inspired gases for early stabilisation of preterm infants across two randomized controlled trials: Main outcomes and GRADE quality of evidence

Outcome	# of neonates assessed	Heating and humidification (% neonates)	Control (% neonates)	Relative risk (95% CI)	Quality of evidence (GRADE score)
Admission hypothermia (< 36.5 °C)	476	27.5	43.0	0.64 (0.50, 0.83)	High
Admission normothermia (36.5–37.5 °C)	476	59.4	47.1	1.26 (1.06, 1.49)	High
Admission hyperthermia (> 37.5 °C)	476	12.9	10	1.33 (0.81, 2.17)	Moderate
Admission hypothermia < 28 weeks	210	26.8	43.3	0.61 (0.42, 0.90)	Moderate
Admission hypothermia < 26 weeks	96	29.7	40.8	0.73 (0.42, 1.27)	Low
Severe IVH	476	3.4	7.8	0.44 (0.20, 0.99)	Low (underpowered)
BPD or death	476	40.9	45.0	0.91 (0.74, 1.12)	Low (underpowered)
Surfactant use	476	44.3	50.4	0.89 (0.74, 1.06)	Moderate
Intubated in delivery room	476	29.7	32.2	0.92 (0.70, 1.20)	Moderate

CI = confidence interval; IVH = intraventricular hemorrhage; RR = risk ratio.

DISCUSSION

Admission hypothermia (< 36.5 °C; the primary endpoint) was significantly lower in neonates receiving HHG during initial stabilization and transport to the NICU compared to those receiving cold, dry gas. There was no significant difference between the two groups for the respiratory outcomes and mortality rates. These studies, however, were not designed to assess these endpoints and therefore received lower GRADE scores for quality of evidence.

While no adverse effects of using HHG were reported in the studies, care needs to be taken to avoid hyperthermia. Considerations for implementing HHG in the DR and during transport to the NICU include: early preparation of the circuit, and turning the humidifier on at, or shortly before, delivery with only 30–50 mL of water in the chamber.

KEY POINTS

- Compared to cold, dry gas, the use of HHG when stabilizing preterm infants immediately after birth and during transport to the NICU significantly reduced the rate of admission hypothermia and increased the rate of admission normothermia.
- Use of HHG was not associated with an increase in admission hyperthermia.

GLOSSARY

APGAR SCORE:

A scoring system doctors and nurses use to assess newborns 1 minute and 5 minutes after their birth.

ATELECTASIS:

Atelectasis is the collapse or closure of a lung resulting in reduced or absent gas exchange.

BAROTRAUMA:

Damage to body tissue secondary to pressure difference in enclosed cavities within the body.

BRONCHOPULMONARY DYSPLASIA (BPD) OR CHRONIC LUNG DISEASE:

A chronic lung condition that affects neonates who were born prematurely or required respiratory support after birth.

DR:

Delivery room

ENDOTRACHEAL TUBE (ETT):

A tube inserted through the mouth or nose into the trachea to maintain an unobstructed airway.

EXTUBATION:

Withdrawing an endotracheal tube (ETT) from a patient's airway.

FLOW-INFLATING BAG (FIB):

A handheld resuscitation device that fills with gas from a compressed flow source.

FULL-TERM:

An infant born between 37- and 40-weeks' gestation.

FUNCTIONAL RESIDUAL CAPACITY (FRC):

The volume of air that remains in the lungs following a typical expiratory phase. This volume is important for keeping the lungs open post exhalation and for ensuring adequate pulmonary gas exchange.

GRADE APPROACH:

Grading of Recommendations, Assessment, Development, and Evaluations is the most widely adopted tool for grading the quality of evidence and for making recommendations.

GA:

Gestational age.

HYPOTHERMIA:

A condition where the body loses heat faster than it can produce it.

INTRAVENTRICULAR HEMORRHAGE (IVH):

Bleeding into the ventricles of the brain (occurs most often in premature infants).

IN UTERO:

A Latin term literally meaning "in the womb" or "in the uterus".

INTUBATION:

The insertion of an ETT or tracheostomy tube into the trachea.

LUNG COMPLIANCE:

The ability of the lungs to stretch during a change in volume relative to an applied chamber pressure.

NICU:

Neonatal Intensive Care Unit

NORMOTHERMIA:

Normal body temperature. (36.5–37.5°C)

PEAK INSPIRATORY PRESSURE (PIP):

The highest pressure applied to the lungs during inspiration.

PERINATAL ASPHYXIA (ALSO KNOWN AS NEONATAL ASPHYXIA OR BIRTH ASPHYXIA):

Occurs when an infant doesn't receive enough oxygen before, during, or just after birth.

PNEUMOTHORAX:

A collapsed lung. Occurs when air leaks into the space between the lung and the chest wall.

POSITIVE END-EXPIRATORY PRESSURE (PEEP):

This is the pressure in the lungs above atmospheric pressure (the pressure outside of the body) that exists at the end of expiration.

PRETERM:

An infant born before 37 weeks gestation regardless of their weight. Usually, preterm infants are found in the NICU of the hospital on some form of respiratory support. They can be further divided into:

- **Moderate to late preterm**
  32 to < 37 weeks gestation.
- **Very preterm**
  28 to < 32 weeks gestation.
- **Extremely preterm**
  < 28 weeks gestation.

QUASI-RANDOMIZED TRIAL:

A quasi-randomized trial is one in which participants are allocated to different arms of the trial using a method of allocation that is not truly random. With quasi-randomization there is a greater risk that the investigator will be aware of which participant is in which group. There is therefore a risk of selection bias.

RANDOMIZED CONTROLLED TRIAL (RCT):

A type of scientific (often medical) experiment that aims to reduce certain sources of bias when testing the effectiveness of new treatments.

SELF-INFLATING BAG (SIB):

A handheld resuscitation device that fills spontaneously with gas after it has been squeezed.

SURFACTANT:

A substance produced in the lungs that tends to reduce the surface tension of the fluid in the lungs and helps make the small air sacs in the lung (alveoli) more stable.

SUSTAINED LUNG INFLATION (SLI):

Prolonged inflation of the lung.

TIDAL VOLUME (V_T):

Volume of air inspired or expired with each normal breath. The amount of gas delivered to a patient in one breath.

T-PIECE RESUSCITATOR (TPR):

A resuscitation device that provides flow-controlled and pressure-limited breaths, using gas from a compressed flow source.

VOLUTRAUMA:

Lung injury caused by alveolar overdistension.

WORK OF BREATHING (WOB):

The force required to expand the lung against its elastic properties.

For more information please contact your local
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