Aim: To assess the effect of viewing a manometer on the peak inspiratory pressures used, the volume delivered, and leakage from the face mask during PPV with two manual ventilation devices in a model of neonatal resuscitation.

Methods: Participants gave PPV to a modified resuscitation mannequin using a Laerdal infant resuscitator and a Neopuff infant resuscitator at specified pressures ensuring adequate chest wall excursions. Each participant gave PPV to the mannequin with each device twice, viewing the manometer on one occasion and unable to see the manometer on the other. Data from participants were averaged for each device used with the manometer and without the manometer separately.

Results: A total of 7767 inflations delivered by the 18 participants were recorded and analysed. Peak inspiratory pressures delivered were lower with the Laerdal device. There were no differences in leakage from the face mask or volumes delivered. Whether or not the manometer was visible made no difference to any measured variable.

Conclusions: Viewing a manometer during PPV in this model of neonatal resuscitation does not affect the airway pressure or tidal volumes delivered or the degree of leakage from the face mask.

Abbreviations: PEEP, positive end expiratory pressure; PIP, peak inspiratory pressure; PPV, positive pressure ventilation; VTE(mask), expiratory tidal volume at the mask; VTI(mask), inspiratory tidal volume at the mask

ORIGINAL ARTICLE

Neonatal resuscitation 3: manometer use in a model of face mask ventilation

C P F O’Donnell, P G Davis, R Lau, P A Dargaville, L W Doyle, C J Morley


Background: Adequate ventilation is the key to successful neonatal resuscitation. Positive pressure ventilation (PPV) is initiated with manual ventilation devices via face masks. These devices may be used with a manometer to measure airway pressures delivered. The expiratory tidal volume measured at the mask (VTE(mask)) is a good estimate of the tidal volume delivered during simulated neonatal resuscitation.

Aim: To assess the effect of viewing a manometer on the peak inspiratory pressures used, the volume delivered, and leakage from the face mask during PPV with two manual ventilation devices in a model of neonatal resuscitation.

Methods: Participants gave PPV to a modified resuscitation mannequin using a Laerdal infant resuscitator and a Neopuff infant resuscitator at specified pressures ensuring adequate chest wall excursions. Each participant gave PPV to the mannequin with each device twice, viewing the manometer on one occasion and unable to see the manometer on the other. Data from participants were averaged for each device used with the manometer and without the manometer separately.

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Figure 1 Error bars showing mean and 95% confidence intervals for mean peak inspiratory pressure delivered with each device used without and with the manometer visible.

Table 1 Mean peak inspiratory pressure (PIP), expiratory tidal volume at the mask (VTE(mask)), and leakage from the face mask as a percentage of inflation volume (VTI(mask)) for each device without and with the manometer visible.

<table>
<thead>
<tr>
<th>Device</th>
<th>PIP (cm H2O)</th>
<th>VTE(mask) (ml)</th>
<th>VTI(mask) (ml)</th>
<th>Leak (% of VTI(mask))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laerdal</td>
<td>21.0 (4.7)</td>
<td>6.3 (3.7)</td>
<td>33.0 (36.4)</td>
<td></td>
</tr>
<tr>
<td>Laerdal with manometer</td>
<td>21.3 (4.9)</td>
<td>6.2 (2.5)</td>
<td>13.6 (29.1)</td>
<td></td>
</tr>
<tr>
<td>Neopuff</td>
<td>24.7 (1.6)</td>
<td>5.7 (3.9)</td>
<td>34.3 (41.1)</td>
<td></td>
</tr>
<tr>
<td>Neopuff with manometer</td>
<td>24.8 (1.7)</td>
<td>5.2 (3.5)</td>
<td>35.8 (40.8)</td>
<td></td>
</tr>
</tbody>
</table>

Data are mean (SD).
RESULTS

Participants
Eighteen staff members (five consultant neonatologists, three fellows, five residents, and five neonatal nurses) participated in this study.

Measurements
A total of 7767 inflations were recorded from the 18 participants using each of the four device-manometer/no manometer combinations. This yielded summary statistics for 72 participant-device-manometer/no manometer combinations.

Peak inspiratory pressure (PIP)
There was significantly greater variability in the PIP delivered with the Laerdal than that delivered with the Neopuff ($F = 41.2$, $p < 0.0001$), reflected by the wider confidence intervals surrounding the mean PIP delivered with the Laerdal (table 1, fig 1). The PIP delivered with the Laerdal was lower than that delivered with the Neopuff (mean difference $-3.6 \text{ cm H}_2\text{O}$, 95% CI $-5.6$ to $-1.6$; $p = 0.001$). Whether or not the manometer was visible made little difference in the mean PIP delivered with either device.

Expiratory tidal volume at the mask ($V_{TE(mask)}$)
There were no significant differences in $V_{TE(mask)}$ delivered between or within devices whether or not a manometer was visible (table 1, fig 2).

Percentage of gas leak from the face masks
There were no significant differences in the leaks from the face masks between or within devices whether or not a manometer was visible (table 1, fig 3).

DISCUSSION

We used the most popular resuscitation mannequin, which is used worldwide to teach and practise bag-valve-mask ventilation techniques. It is considered to be the most realistic mannequin for the purposes of mask ventilation. It is unclear, however, how closely this model resembles the newborn infant.

Viewing the manometer did not improve the accuracy with which airway pressures, or tidal volumes, were delivered with either device. Although this is not surprising for the Neopuff, as the desired pressures are preset, it surprised us that the accuracy of delivering a prescribed airway pressure did not improve with the Laerdal bag when the manometer was visible. This finding contrasts with that of a previous study of the impact of a manometer on airway pressures delivered to a mannequin with a self inflating bag.

The rationale for using a manometer during neonatal resuscitation is to avoid giving “excessively high” pressures to the infant, thereby limiting the risk of over-distension of the lung and consequent air leak. There is no evidence that use of a manometer during resuscitation reduces lung damage during mask ventilation. We have shown that the inflating pressure is a poor proxy for the tidal volume delivered during mask ventilation and that the tidal volume delivered is influenced by the face mask leakage. We have shown that seeing a manometer had no impact on the tidal volumes delivered. Leaks from the face mask were considerable for each device whether or not the manometer was visible. This was consistent with our previous study. The utility of a manometer during neonatal resuscitation is therefore debatable.

It is commonly believed that, for flow driven devices such as the Neopuff, the manometer allows the operator to detect leaks. However, we have shown that it is possible to deliver

**What is already known on this topic**

- Manometers are commonly used to monitor the pressures used during PPV with manual ventilation devices and face masks
- Their effect on the pressures used, tidal volumes delivered, and leakage from the mask during neonatal resuscitation is unknown

**What this study adds**

- Manometer use did not affect the pressures used, tidal volumes delivered, or the degree of leak from the mask during PPV in this model of neonatal resuscitation
- Leaks are not reliably identified on manometers and the value of a manometer during manual ventilation via a mask is thus unclear
target airway pressures even when there are substantial leaks at the face mask with this device. Thus leaks from face masks cannot be reliably detected with manometers. It may be argued that the more important role of the manometer should be to give an estimate of the pressure required to inflate the infants' lungs once the chest is seen to move with manual ventilation, rather than to determine or limit the pressure given. The size and variability of leakage at the mask means that the inflating pressure required to move the chest during mask ventilation is unlikely to be a good estimate of the peak inflating pressure required to ventilate an infant through an endotracheal tube. Furthermore, the clinical assessment of chest wall movement is inferior to direct measurement of the tidal volume delivered in determining assessment of chest wall movement is inferior to direct measurement of the tidal volume delivered in determining appropriate pressures for mechanical ventilation via an endotracheal tube in newborn infants. Measurement of tidal volume, rather than reliance on observing inflating pressure, during ventilation of infants should be the gold standard irrespective of the setting or device used.

CONCLUSION
During face mask ventilation of a neonatal resuscitation mannequin, the use of a manometer does not affect the airway pressures used, tidal volumes delivered, or leakage from the face mask. Clinical studies to determine the most effective devices and techniques to give PPV to newborns at delivery are urgently needed.

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