Monitoring during resuscitation
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Why should monitor during neonatal training and resuscitation?

Ventilation during resuscitation has traditionally relied on subjective assessment of chest rise. This was used for assessing the effectiveness of ventilation in the NICU but now mostly the waves and data shown on ventilator screens are used to provide better information about the ventilation.

A neonatal resuscitation monitor (RFM) is similar. It simply consists of flow and pressure sensors and displays the data and waves on a screen, together with heart rate and pulse oximetry and end tidal CO2.

It has been shown that neonatal staff are not good at assessing many aspects of ventilation during neonatal resuscitation, particularly chest rise, mask or endotracheal leaks, size of tidal volumes, inflation or expiration times, whether an endotracheal tube is in the trachea, airway obstruction during inflations, change in lung compliance, spontaneous breathing and its tidal volume, and how these are related to inflations.

Using a RFM has shown mask leak is usually unrecognized and very variable during resuscitations due to the baby’s movements, movements of the mask or procedures such as fitting a hat. Variable mask leak leads to delivery of variable tidal volumes. When the leak is large, tidal volumes may be insufficient to achieve adequate gas exchange. Conversely, if the leak is small the tidal volumes may be excessive and cause over ventilation and lung damage. Unsatisfactory mask technique may cause failed mask ventilation and increase the incidence of endotracheal intubation. With a RFM resuscitators are able to adjust mask position and reduce the leak. Using a RFM improves the effectiveness of ventilation via a mask by providing immediate feedback to the operator.

When assessment of chest rise was compared with the delivered tidal volumes the correlation was weak. So an RFM is a more accurate way of assessing the tidal volumes delivered.

Measuring and displaying mask leak and delivered tidal volume teaches staff how to adjust their hold on the face mask, and alter the pressure to provide an appropriate tidal volume at a reasonable inflation time and rate. It shows that a set peak inflating pressure does not deliver a set tidal volume.

Failure to achieve a set PIP or PEEP with a T-piece device is probably due to a large mask leak. If this is seen the resuscitator should alter the mask position to restore the pressures and minimize the leak.

The same principles apply during ETT intubation. After the first inflation a RFM will show correct ETT placement by displaying gas flow in and out of the trachea. If the ETT is not in the trachea, the flow wave shows gas going down the ETT but not returning.

Most premature babies breathe spontaneously during ventilation. This is often unrecognized or not considered to be a problem. However, if an inspiration coincides with an inflation it can result in a potentially dangerously high tidal volume. If a baby is apnoeic then inflations given with recommended pressures may have an inadequately low tidal volume.

Accidental esophageal intubation is quite common. Although a CO2 detector is frequently
used for assessing a misplaced ETT it takes several inflations before a lack of color change is recognized. With a RFM if the ETT is not in the trachea immediately there will be inspiratory flow but no expiratory flow. Also if an ETT is dislodged, this can be seen immediately as there is inspiratory flow but little or no expiratory flow.

Immediately after birth expired CO₂ measurement is useful to determine whether gas exchange is occurring. In some babies with slightly low tidal volumes no expired CO₂ is measured. By increasing the tidal volumes CO₂ appears and the baby improves.

An increase in heart rate is the best indicator that effective ventilation is being delivered. Intermittently counting the heart rate for a short time and multiply to get the rate/min is inaccurate, can not show rapid changes, and may interfere with the resuscitation. Measuring and displays heart rate from an ECG, or pulse oximeter, is much better because it shows the dynamic changes occuring during resuscitation.

All babies are cyanosed when they are born and, depending on their breathing and ventilation, oxygenate over the first few minutes. Measuring and displaying SpO₂ can show how this is changing and help decide whether the FiO₂ should be altered.

After intubation a reason for unsatisfactory ventilation might be the ETT is too small. This can cause a large leak around the ETT and result in ineffective ventilation. Using a RFM enables the operator to assess the degree of leak as soon as inflations are applied and decide whether the ETT size is appropriate or needs to be changed. The appropriate tidal volume for various phases of resuscitation is unknown.

Studies of normal infants, animal studies, and our observations suggest the expired tidal volume (V₁ₑ) during resuscitation should be 4–8 ml/kg. Excessive V₁ₑ can cause volutrauma, whereas insufficient V₁ₑ leads to inadequate gas exchange. A RFM enables the resuscitator to see a graphical and numerical output of the V₁ₑ and adjust the PIP to ensure an appropriate V₁ₑ is delivered.

If there is little or no V₁ₑ displayed on the RFM during an inflation, then either the peak pressure is too low or the airway is obstructed. The clinical response to a very low VT should be to increase the PIP until an appropriate V₁ₑ is displayed on the RFM. High inflating pressures will not injure the lungs if the V₁ₑ is monitored and maintained in the appropriate range. It is not uncommon for an apnoeic infant to require a high PIP initially to aerate the lungs. This can be assessed by using a RFM to display the tidal volumes.

If there is little or no increase in a very low V₁ₑ in response to increased PIP then the resuscitator should consider obstruction to the airway. Obstruction can be due to the mask being applied too tightly and obstructing the nose and mouth. This can be identified and corrected by releasing the mask a little and observing the gas flow and volume signals. Or the neck may be hyperflexed. This can be diagnosed by observing the signals as the head is repositioned. Obstruction may also be due to glottic closure.

Many resuscitators are unaware of their ventilation rate. High rates can lead to inappropriately short inflation and expiration times with the risk of either inadequate V₁ₑ delivery or air trapping. A high rate and satisfactory V₁ₑ will rapidly cause hypocarbia. A RFM enables the resuscitator to see the rate, inflation and expiration times, and adjust as necessary.
The inflation time should be long enough to allow an appropriate $V_{Te}$ to be delivered. Sharply spiked volume waves indicate the inflation time is too short. If the inflation time is too long there will be no increase in $V_{Te}$ towards the end of inflation. Using a RFM enables the resuscitator to see what is happening.

The expiratory flow wave should return to zero before the next inflation starts. If the expiratory time is too short gas trapping will occur.

A RFM attached to a mask or ETT shows an infant’s spontaneous tidal volumes, breathing patterns and interaction with any inflations. If the infant is breathing regularly and generating adequate tidal volumes, ventilation may be stopped and the infant managed either with no assistance or CPAP. Infants have their own respiratory rate and inspiratory and expiratory patterns regardless of any inflations. A RFM often shows an infant breathing out of phase with the inflations. A trial of CPAP may be appropriate.

Inexperience and lack of knowledge about the displayed waveforms may lead to misinterpretation of the signals. Therefore anyone using a RFM must be trained to interpret pressure, flow and tidal volume signals. With an RFM, the numerical value for leak is averaged over 1 min and so cannot be used for individual inflations. A RFM only displays the waves and data to aid the resuscitator and does not provide interpretation of the signals or a diagnosis.

There are now many studies about the techniques and results of monitoring neonatal resuscitations. Seeing an objective display of what is happening to the baby’s ventilation, heart rate, SpO2 and end tidal CO2 gives staff more control and understanding of what is happening and empowers them then to help the baby transition as safely as possible. This is what we do all the time in the NICU. There is no reason why we should have lower standards during a resuscitation of a sick baby at birth.

References
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