Overview of assisted ventilation in the newborn

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Abstract

Respiratory support of the newborn is an integral part of newborn care. This can be provided non-invasively using a nasal interface, or invasively through an endotracheal tube. The choice of support depends upon the infant's respiratory drive, severity of lung disease and airway patency. Current practice of mechanical ventilation to assist spontaneous breathing in newborn has improved over the years. The utilization of microprocessor technology in newborn ventilation has allowed delivering small tidal volumes and utilising newer modes of ventilation that have a potential to limit ventilation induced lung injury (VILI). However, optimizing respiratory support to match the needs of the babies still remains a challenge and newer modes of ventilation need to be assessed in babies through well-designed trials.

Keywords CPAP; oxygen; preterm; respiratory support; ventilation; ventilation induced lung injury

Introduction

During spontaneous breathing rib cage expands and diaphragm contracts. This results in expansion of the lung, drop in intra-thoracic pressure and flow of air from the atmosphere into the lungs. This cycle reverses during expiration when diaphragm relaxes, chest recoils and positive intra-thoracic pressure forces air to flow out of the lungs to the atmosphere. The first ventilator developed during the polio epidemics in the early 1900s, the 'Iron Lung', was a negative pressure ventilator and widely used with good result. However due to the bulky apparatus and patient confinement, 'Iron Lung' lost its popularity. Compactness, portability and ease of use led to widespread use of modern ventilator systems since 1950s.

A major development in neonatal ventilation occurred with the introduction of Continuous Positive Airway Pressure (CPAP) by Gregory that supported spontaneously breathing infants using Bubble CPAP. However, infants needing invasive respiratory support through endotracheal tube received it through modification of adult ventilators. These were continuous flow, time cycled, and pressure limited devices. The combination of intermittent positive pressure breath with spontaneous breaths, while utilising continuous gas flow was called Intermittent Mandatory Ventilation (IMV). A significant problem with this mode was 'fighting the ventilator' and need for paralysis due to patient ventilator asynchrony. One of the complications of ventilation in newborn first described by Northway et al in 1968 was called bronchopulmonary dysplasia. It was attributed to positive pressure ventilation although initially thought to be due to oxygen toxicity. Innovation in microprocessor technology in the 1990s led to emergence of various patient triggered ventilation modes with a potential for better patient ventilator synchrony and patient comfort.

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Physiology of ventilation

Understanding the key concepts of mechanics of breathing is important for setting the ventilator and matching the needs of the patient and disease patho-physiology. These are:

- Resistance and compliance of the breathing apparatus
- Time constant.

Resistance is expressed in terms of a change in pressure divided by flow. The standard units of resistance are cm H_20/L/second. An example of increased airway resistance is bronchopulmonary dysplasia. Compliance is expressed as a change in volume divided by a change in pressure. An example of low compliance is surfactant deficiency in preterm infants. Time constant determines the time necessary for alveolar pressure to reach 63% of a change in airway pressure. Mathematically, the time constant is defined as compliance times the airway resistance. This is expressed in units of seconds of time. Thus, poorly compliant lung have short time constant and accordingly will need short inspiratory time, and conditions with increased airway resistance have longer time constants and thus benefit from longer inspiratory times.

The interplay of these factors is expressed in a mathematical model commonly referred to as equation of motion.

$$\begin{aligned}&\text{Respiratory Muscle Pressure} + \text{Ventilator Pressure}\\&\quad = (1/\text{compliance} \times \text{volume}) + (\text{Resistance} \times \text{flow})\end{aligned}$$

When applied in assisted ventilation, we can infer:

- When ventilator pressure is zero this is normal unassisted breathing
- If the ventilator provides more flow than is demanded then airway pressure will rise above baseline and the breath is 'assisted'.
- If both respiratory muscles and the ventilator pressure are not zero then this is called partial ventilatory support
- If the muscle pressure is zero then the ventilator provides all the work of breathing and this is total ventilatory support

Mechanical ventilation

Assisted ventilation could be defined as the movement of gas into and out of lungs by an external source connected directly to the patient. The external source could be the resuscitation bag, continuous distending pressure device or a mechanical ventilator.

A mechanical ventilator has four parts. A pressurized source of either air or oxygen that acts as a driving force, a blending chamber that receives this mixture, a flow control that regulates how much is delivered to the patient and an exhalation valve. Between the air/oxygen source and the exhalation valve there is a continuous flow available to help the infant breathe spontaneously which is also called as "bias flow".

The aim of mechanical ventilation would be to replicate normal physiologic process of delivering a tidal volume breath. Generally 4–8 ml/kg is the starting point. This is further titrated depending upon the disease pathology and gestation with older infants needing more than 6 ml/kg.

Mechanical ventilation could be patient triggered or controlled by the device. In the UK, most neonatal units prefer patient triggered modes. Patient triggering can be achieved through many interfaces, but use of hot wire anemometer or variable orifice differential pressure transducer (pneumotachograph) is the most sensitive method with a typical response time of 5–25 milliseconds. The aim is to achieve synchrony and deliver the tidal volume in the early part of inspiration. Trigger mechanism could be change in pressure or change in the flow sensed by the ventilator. The trigger threshold in flow trigger method is usually set at 0.2–0.5 L/min. This means, for every 0.2 L air or oxygen displacement detected in the bias flow the ventilator would offer the preset ventilatory support. Trigger threshold to identify expiration (usually a set percentage of the peak flow) can also be included to help synchronize spontaneous breathing at expiration. The advantage is patient comfort and patient regulation of its spontaneous breathing. This concept of synchrony during expiration is called flow cycling. An exciting development in patient triggered mode is synchronizing with neural impulses to identify diaphragm contraction to gain assisted breath. This will be discussed later in the article.

Methods of providing mechanical respiratory support include

Mechanical ventilation strategies to provide assisted support could be divided into

- Tidal ventilation (conventional)
- Non tidal ventilation e.g. high frequency oscillation where respiratory support strategy utilizes sub physiological tidal volumes with extremely high rate.

The mechanical ventilators are broadly classified into volume or pressure modalities. In volume controlled ventilation, the volume delivery is consistent but the pressures vary to deliver the desired tidal volume. The flow to achieve this tidal volume is constant and has non decelerating square waveform.

In a pressure controlled ventilation, preset pressures are consistently achieved with variable volume delivery depending upon the compliance of the lungs and the flow pattern is crescendo–decrescendo type. Each modality of ventilation have their advantages and disadvantages. Regardless of the chosen modality it is important to remember that inadvertent injury to lungs due to assisted ventilation should be limited (Figure 1).

Patient triggered modes include

- Assist control ventilation
- Synchronized intermittent mandatory ventilation
- Pressure support ventilation

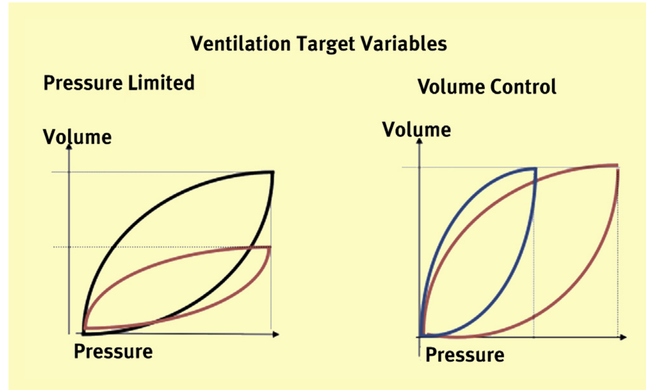

Figure 1 Ventilation target variables. In pressure limited ventilation as compliance improves, the delivered tidal volume increases at same pressures. In contrast, with volume control ventilation as compliance improves, the tidal volume remains the same but the pressures wean automatically.

- Proportional assist ventilation
- Neurally adjusted ventilator assist

In Patient triggered mode (Synchronized ventilation) the assisted breath can be controlled for three variables (Figure 2):

- Identification of a trigger (spontaneous breath) usually change in flow or pressure
- Control/delivery of the breath using either pressure or volume limit as determined by the clinician
- Termination of the breath (cycling mechanism)- usually determined by a set time or percentage of peak flow.

There are subtle differences between various patient triggered modes. The following section describes salient features of individual modes.

- Assist control ventilation (A/C mode): there are two components of A/C mode that supports its use in preterm infant during the acute phase of illness. The first component is assisting all spontaneous breaths and the second a safety of having a back up rate. The infant gets full support utilising pressure or volume controlled ventilation

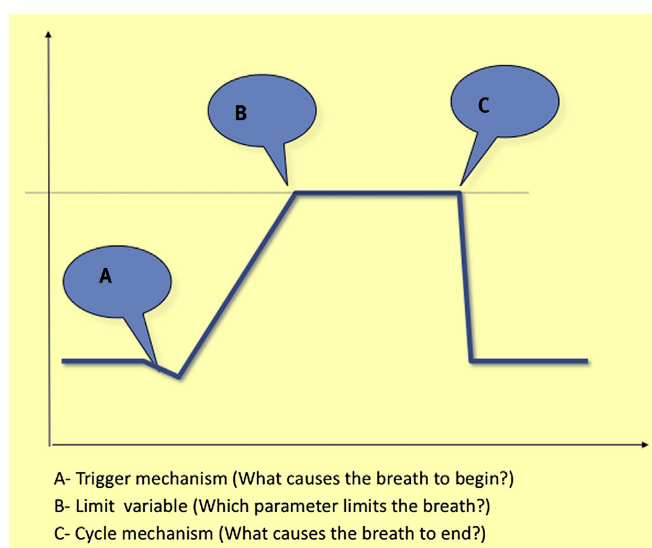

Figure 2 Phase variables.

