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Neonatal Ventilation: A Brief Review

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Abstract

When infants are incapable of achieving satisfactory gas exchange independently, the provision of respiratory assistance becomes imperative. For neonates exhibiting respiratory insufficiency, the utilization of mechanical ventilation plays a vital role in enhancing oxygenation and facilitating the elimination of carbon dioxide. While a majority of infants necessitate ventilation because of pulmonary issues particularly due to respiratory acidosis, there are also instances where other conditions, such as seizures, metabolic acidosis, and shock, contribute to the need for respiratory support. Each ventilation strategy is designed with the objective of bolstering the respiratory systems of infants while concurrently safeguarding both the lungs and the brain against potential damage. It is important to note that brain damage incurred is irreversible. In this concise overview, we will explore the fundamental aspects and provide an overview of ventilation, as well as touch upon a few concepts that are not commonly discussed.

Keywords: Newborn; Ventilation; Ventilators; Lung Injury; Pulmonary Mechanics; Positive Pressure Ventilation

Abbreviations: NICU: Neonatal Intensive Care Unit; CMV: Continuous Mandatory Ventilation; NAVA: Neurally-Adjusted Ventilatory Assistance; PVL: Periventricular leukomalacia; HFO: High-Frequency Oscillation; ABG: Arterial Blood Gas Analysis; PIP: Positive Inspiratory Pressure; PEEP: positive end expiratory pressure; Ti :Inspiratory time; TV: Tidal Volume; HFNC: High-Flow Nasal Canula, MAP: Mean Airway Pressure; PSV: Pressure Support Ventilation; CPAP: Continuous Positive Airway Pressure; IMV: Intermitent Mandatory Ventilation; SIMV: Synchronous Intemtent Mandatory Ventilation; ACM: Assist Control Mode; VAP: Ventilator-Associated Pneumonia

Introduction

Positive pressure mechanical ventilation has been utilized in neonatal intensive care units (NICUs) since the 1960s and 1970s, resulting in significant improvements in neonatal outcomes. However, the survival rate is reported to be 67.9%, with higher rates in more affluent countries and lower rates, ranging from 40 to 60%, in impoverished countries [1]. Over time, there have been advancements and improvisations in ventilators, leading to increased synchronization and decreased invasiveness. This has subsequently resulted in reduced mortality and morbidity rates. Furthermore, the mode of ventilation has also undergone changes, transitioning from non-synchronous conventional mechanical ventilation (CMV) to highly synchronous and non-invasive neurally adjusted ventilatory assist (NAVA) [2]. It is worth mentioning that premature babies, with their still-developing lungs, present a unique challenge when it comes to mechanical ventilation. Consequently, this brief review aims to provide an overview and fundamental understanding of neonatal ventilators.

Discussion

Ventilation means the removal of CO_2, but ventilators only provide inspiration because expiration is passive, except for high-frequency oscillatory (HFO) ventilation, where expiration is active. Practically, however, in some HFO ventilators, expiration is passive. Due to active expirations, CO_2 removal may be more prone to hypocarbia, which leads to periventricular leucomalacia (PVL). That is why we need frequent arterial blood gases (ABGs). Ventilation works on the T-piece principle. In HFO ventilation, where there are high rates and low volumes compared to dead space, molecular diffusion is the primary mechanism of gas exchange. The filtration effect is considered during ventilation, where 90% of mean arterial pressure (MAP) will be attenuated [3]. Because of the low tidal volume, we usually use MAP more than conventional ventilation.

Ventilators have components like compressors, which compress the gases to deliver adequate pressure, particularly for generating positive inspiratory pressure (PIP). Gases in compressors are cold and dry. Ventilators have humidifiers; gases should be humidified before entering the neonatal lung because we bypass the nasal cycle. Particularly premature infants do not have proper nasal cycles [4]. The humidifier takes over the function of the nose. Humidification is a must to prevent endotracheal tube blockage, which may lead to pulmonary hemorrhage. Damaging the cilia causes ventilator-associated pneumonia. Before being connected to the patient, the humidifier should be adequately warm to prevent surfactant denaturation and other effects of cold injury [4]. The thermoneutral boundary is usually at the carina with 37 °C and 100% relative humidity [5,6]. Seeing the circuit, mist, and water in the expiratory limb tells us there is adequate humidification. However, sometimes humidity from a baby's expiratory gases may precipitate in the expiratory limb. That is why it is better to observe the quantity of water in the expiratory tube trap. Dry tubes indicate low humidification. Always maintain the correct water level by connecting the chamber to IV fluid through a connector. In the chamber, there is a valve that will be closed after it reaches the maximum level. Some humidifiers will have seals at two levels. The level of water also creates dead space, particularly in HFO ventilation, where it is more valuable. It is better to cover the humidification probes with aluminum coils to prevent the effect of room temperature and warmer. The ET tube position should be at the proper level, the lower border of the 2nd thoracic vertebra. Do not adjust frequently if the chin is low; the tube will move in. That is why properly positioned X-rays are required before adjustment.

Ventilatory screens or knobs are used to adjust the valves inside the ventilator for appropriate mode and control. The mean airway pressure (Pmaw = [PIP – PEEP] * [Ti/Ttot] + PEEP) will decide the oxygenation, but according to the formula, if we increase the PEEP to 1 cm H_20, the MAP will increase to 1cm H_20. In HFO ventilation, oxygenation and ventilation are usually decoupled.

CO_2 elimination is mainly done by adequate volume and PIP rather than rate because rate is usually controlled by neonates and they do not have to come under total ventilatory control. Before ABG, suction is more appropriate to avoid CO2 retention and calm the patient, because if the baby cries, the CO2 will be eliminated. A transient change in CO_2 may change the bicarbonate, which is why you should always look for standard bicarbonate in ABGs. Low CO_2 causes periventricular leukomalacia in just a few minutes. High CO_2 causes hemorrhage in preterm neonates. Permissive Hypercapnia should be considered to avoid lung injury [7].

The usual settings in Meconium aspiration syndrome (MAS) PEEP are 4 cm H2O and a respiratory rate (RR) of 40 to allow expiration and prevent auto-PEEP. In respiratory distress syndrome, PEEP is 5 and RR may be 50 due to a short-time constant. Because closing volumes are less than functional Resudial capacity (FRC) in neonates, with each breath, the baby lung will collapse and open, unlike an adult lung. That is why adequate PEEP is necessary [6]. In preterm neonates, the inspiratory time is usually short due to short time constants. In assist control mode, we use low Ti and a noninvasive mode, and in pressure support ventilation (PSV), we use long Ti for prevention of atelectasis. In low-compliance and low-resistant cases like RDS, we usually use a high respiratory rate. In highly resistant cases, we use a low rate.

There is no hard-and-fast rule for Ti per disease. It is better to identify it with flow time graphs if we find the inspiratory hold Ti to be decreased. Limiting Ti may result in the redirection of air away from overdistended lung areas (with long time constants) to other areas with short time constants (more homogeneous aeration). Mainstream (proximal) or internal flow sensors are used in neonatal ventilators to detect the inspiratory flow generated by the infant's spontaneous inspiratory effort. Each lung is unique, so better change the settings as per graphics and compliance and resistance values on ventilators. Ventilatory graphics are very useful for knowing lung dynamics in total. For example, if the pressure wave form is rectangular, it is in pressure control ventilation. Should understands the ventilatory graphics for providing gentle ventilation. It is better to mention here that each loop usually does not indicate a single respiration; it is a combination of some of the respirations. Recruitment manurer should be done, because PEEP has a narrow range and is usually done by PIP, but practically, it is difficult to find the maximum distending pressure by SpO2. Then it is better to go with TV. Peak pressure (Ppeak) and plateau pressure (Pplat) are usually seen in volume control ventilation, but in pressure control ventilation, due to decremental responses, we usually do not see them. Ppeak and Pplat are usually needed to identify dynamic and static compliance. In tube blockage and bronchopulmonary dysplasia, where the bronchial tree evolved in pathology, Ppeak will increase. Recruitment is usually done in HFO. In neonates, conventional ventilation recruitment is not indicated because usually PEEP has a narrow range and can only go with PIP in infants older than neonates. After recruitment, ventilation will occur on the descending limb of the compliance curve, where maximum expansion will be present [8].

A classic experiment on rabbits showed volume trauma was more dangerous than pressure trauma [9]. Different modes of ventilation will be present depending on synchronization with the infant and how to assist the infant's breathing. Previously controlled mandatory ventilation (CMV) ventilation usually delivered breathing irrespective of the baby's breaths, leading to more asynchrony. After that, more synchronized intermitent mandatory ventilation (IMV) and synchronized mandatory ventilation (SIMV) came. In SIMV, breathing will support only a time window of 0.5 sec. In neonates, because the breathing is not synchronized, they have to breathe against a narrow tube, which makes breathing harder. That is why we usually add pressure support (PSV) mode, where nonassisted breaths will be supported. In PSV mode, airway resistance is usually decreased. It is analogous to gas blowing from a ventilator through tubes to

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reduce the tube resistance. Because PSV mode is flow-triggered, it is more synchronized than other modes because the baby will experience negative pressure, when the ventilator is giving them breath. In assist control mode, every breath will be supported; this mode will decrease the number of weaning days. As in SIMV, some breaths should be taken by the baby because of their increased work of breathing. But in hyperventilation, assisted controlled ventilation causes auto-PEEP because the ventilator only provides inspiration, and expiratory time is usually reduced, leading to auto-PEEP.

Synchrony is not present in IMV or CMV. There is moderate synchronization in SIMV; some inspiratory synchrony will be there but not expiratory. In AC mode, there is total inspiratory synchrony, but not in expiratory mode. In PSV, both inspiratory and expiratory synchrony will be present. In CMV, SIMV, and IMV, the baby does not control any of the parameters. In AC, the baby controls the respiratory rate. In PSV, the baby controls RR and Ti. In PSV + VG, the baby controls TI, RR, and PIP. Although anatomic dead space is low in preterm neonates, overall anatomic and instrumental dead space per kg is usually high. That is why we use more volume in hybrid control ventilators.

Phase variables are trigger and cycle; the trigger limit determines which initiates the breath. For example, in SIMV and PSV, breaths will be triggered by the baby's negative flow, and SIMV breaths will be triggered by the ventilator, which provides the breaths at particular times. Because volume-targeted ventilators decrease bronchopulmonary dysplasia (BPD) and ventilatory days, proximal flow sensors are the most accurate. Most neonatal ventilators are flow-triggered ventilators because they are sensitive, but pressure sensors are somewhat blunt. In most ventilators, we cannot control the flow delivered to the baby except in volume control mode, where we can regulate the volume by flow and rise time [10]. But some ventilators have built-in flow sensors and pressure sensors. Cycle refers to the end of the inspiration; usually the flow cycle and time cycle are present. Control variables is important. We can usually manage inspiration by using pressure control or volume control ventilation, but each has its own advantages and disadvantages. However, in neonates, hybrid control is used because both volume and pressure control will be available. In this mode, we can accurately control the volume with targeted pressure. If the baby was asynchronized, remove the ET tube from ventilators and see for distress; if not, check and change the variables.

Weaning: The process of weaning begins by addressing more dangerous variables, such as oxygen levels, followed by PIP. However, this process is not always the same. For instance, in cases of persistent pulmonary hypertension, it is necessary to gradually wean both FiO2 and PIP. Rapidly decreasing these variables may result in the need for higher settings and prolonged ventilation due to pulmonary vasoconstriction. Fio2 can be adjusted frequently during rounds based on Spo2 levels [11]. Before extubation, it is important to determine whether the indications for intubation have been resolved. Planned weaning is to be considered, particularly in prolonged ventilation. As usual Feeding should be avoided for a few hours, and the baby should be immediately placed on CPAP or HFNC to prevent atelectasis. Edema and excessive fluid are major concerns, particularly when fluid balance is not strictly monitored or in cases of sepsis where there is extravasation of fluids due to capillary endothelial integrity. When laryngeal edema is suspected, it is advisable to administer a low dose of steroids before extubation and place the baby in a prone position to prevent stridor. During the time of extubation, the baby should be in ACM rather than SIMV, as they need to take a few breaths from the ET tube like a straw, which may result in extubation failure.

In terms of adjuvant therapies, humidification is of utmost importance, as previously discussed. It is recommended to assign one nurse to each critical baby. VAP bundles, including proper positioning, hand washing, and preventing tube soiling, should be implemented. As the endotracheal tube is a foreign body, babies may secrete more secretions. Suctioning should only be performed when there is visible secretion, and repeated suctions should be avoided. Suctioning should be done quickly to minimize the risk of bradycardia, hypoxia, and intraventricular hemmorrhage, especially in preterm neonates within the first 7 days when the germinal matrix is still immature. Proper nutrition is essential to prevent extra uterine growth restriction, which can lead to the inability to create tidal volumes due to inadequate lung growth [12].

It is important to thoroughly read the manual of the ventilator and have contact information for biomedical personnel in case of difficult situations. Troubleshooting skills should be maximized. Alarms should be managed carefully to avoid disturbing the NICU environment. It is crucial to have a comprehensive understanding of the specific ventilator being used, including its hardware. When sudden deterioration occurs on ventilators, potential causes to consider include displaced tubes, obstruction, pneumothorax, and equipment failure. A better understanding of the ventilator is more important than looking for advanced ventilators.

Complications such as ventilator-induced lung injury, ventilator-associated pneumonia, pneumothorax, and pulmonary interstitial emphysema are common in preterm babies due to increased alveolar capillary thickening, unlike term babies, where it was thin and causing pneumothorax. However, these complications can be effectively resolved with the use of HFO [13].

Conclusion

In conclusion, a thorough understanding of different types of assisted mechanical ventilation and the underlying pathophysiology of lung problems is crucial for providing appropriate respiratory support to critically ill neonates. As neonates undergo different phases of lung development, they become more susceptible to ventilator-induced lung injury. Non-invasive, synchronized, gentle, sensitive, and open lung ventilation,

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as well as permissive hypercapnea, are necessary. Each NICU should establish protocols to avoid confusion caused by individual medical decisions.

References

1. Kacmarek RM (2011) The mechanical ventilator: past, present, and future. Respir Care 56(8): 1170-1180.
2. Rossor TE, Hunt KA, Shetty S, Greenough A (2017) Neurally adjusted ventilatory assist compared to other forms of triggered ventilation for neonatal respiratory support. Cochrane Database Syst Rev 10(10): CD012251.
3. Ventre KM, Arnold JH (2014) High Frequency Oscillatory Ventilation. Pediatric Critical Care Medicine 20: 175-193.
4. Tana M, Tirone C, Aurilia C, Lio A, Paladini A, et al. (2023) Respiratory Management of the Preterm Infant: Supporting Evidence-Based Practice at the Bedside. Children (Basel) 10(3): 535.
5. Al Ashry HS, Modrykamien AM (2014) Humidification during mechanical ventilation in the adult patient. Biomed Res Int 2014: 715434.
6. Luciano Gattinoni, John J Marini, Antonio Pesenti, Michael Quintel, Jordi Mancebo, et al. (2016) The “baby lung” became an adult. Intensive Care Med 42: 663-673.
7. Bigatello LM, Patroniti N, Sangalli F (2001) Permissive hypercapnia. Curr Opin Crit Care 7(1): 34-40.
8. Miedema M, McCall KE, Perkins EJ, Oakley RB, Pereira-Fantini PM, et al. (2019) Lung Recruitment Strategies During High Frequency Oscillatory Ventilation in Preterm Lambs. Front Pediatr 6: 436.
9. Beitler JR, Malhotra A, Thompson BT (2016) Ventilator-induced Lung Injury. Clin Chest Med 37(4): 633-646.
10. Campbell RS, Davis BR (2002) Pressure-controlled versus volume-controlled ventilation: does it matter? Respir Care 47(4): 416-424.
11. Soydan E, Ceylan G, Topal S, Hepduman P, Atakul G, et al. (2022) Automated closed-loop FiO_2 titration increases the percentage of time spent in optimal zones of oxygen saturation in pediatric patients-A randomized crossover clinical trial. Front Med (Lausanne) 9: 969218.
12. Martinez EE, Smallwood CD, Bechard LJ, Graham RJ, Mehta NM (2015) Metabolic assessment and individualized nutrition in children dependent on mechanical ventilation at home. J Pediatr 166(2): 350-357.
13. M Pons Odena, FJ Cambra Lasaosa (2003) Mechanical ventilation in pediatrics (III). Weaning, complications and other types of ventilation. Noninvasive ventilation]. An Pediatr (Barc) 59(2):165-172.

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