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Review Article

Overview of Newer Concepts in Neonatal Resuscitation

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Abstract

This article aims to examine non-invasive methods of respiratory support and other strategies to mitigate the negative impacts of invasive mechanical ventilation. Despite significant progress in medicine, the morbidity rate among surviving high-risk neonates has risen, even as mortality rates have fallen. Over the past thirty years, the use of sophisticated invasive mechanical ventilation techniques has greatly enhanced the survival rates of high-risk neonates. Yet, with every medical breakthrough, while death rates have declined, the morbidity among surviving high-risk neonates has escalated. The advent of assisted ventilation has been linked to bronchopulmonary dysplasia a condition not known before the use of mechanical ventilation. This has resulted in a group of patients who are dependent on ventilators or oxygen and suffer from severe pulmonary and neurodevelopmental morbidity. The airways of young infants are highly flexible and prone to damage during mechanical ventilation. In the initial hours of life, all infants have a higher surface tension in the alveoli, and some degree of atelectasis is common until a monomolecular layer of surfactant is formed at the air-liquid interface. It appears that surface tension and structural immaturity are the primary contributors to respiratory insufficiency in the premature lung, potentially leading to respiratory distress syndrome (RDS). This review provides a comprehensive overview of the latest developments and strategies in neonatal respiratory therapy, with a particular focus on managing RDS.

Keywords: *Non-Invasive Ventilation (NIV); Respiratory Distress Syndrome (RDS); Neonatal Respiratory Therapy; Neonatal Resuscitation*

Non-invasive ventilation

Non-invasive ventilation (NIV) is a method of providing respiratory support that does not require direct tracheal intubation. Bronchopulmonary dysplasia (BPD) is often linked to the duration of invasive mechanical ventilation and oxygen therapy. NIV is frequently used to treat preterm infants with respiratory distress syndrome (RDS), helping to avoid intubation and thus reducing the risk of lung injury caused by ventilators.

Common forms of NIV include nasal continuous positive airway pressure (NCPAP), nasal intermittent positive pressure ventilation (NIPPV), bi-level positive airway pressure (BiPAP), and high-flow nasal cannula (HFNC).

NCPAP provides a steady positive pressure throughout the respiratory cycle, which helps to open up collapsed alveoli, reduce airway resistance, achieve functional residual capacity (FRC), and prevent the collapse of the airway. NIPPV provides intermittent positive pressure driven by flow at predetermined intervals. BiPAP delivers cycles of high and low positive pressures at set intervals. HFNC supplies heated and humidified oxygen at a flow rate of 2 - 8 L/min through a nasal prong, creating a positive end-expiratory pressure. HFNC can help to reduce the physiological dead space, decrease the resistance in the nasopharyngeal airway, and prevent the drying of the airway mucosa [1].

Current comparisons of NIV use: In preterm infants with very low birth weight and RDS, both NIPPV and NCPAP have shown similar outcomes in terms of failure to extubate, BPD, intraventricular hemorrhage, air leaks, necrotizing enterocolitis, and the length of respiratory support required. However, synchronized NIPPV (SNIPPV 2) and a combination of SNIPPV and NCPAP have demonstrated a higher success rate in extubation and discontinuation of NIV within a week compared to NCPAP alone. Furthermore, SNIPPV has significantly decreased the occurrence of bradycardia and apnoea in preterm infants. These observations indicate the critical role of synchronization in delivering effective respiratory support. Asynchronies can disrupt the rhythm of spontaneous breathing, increase the work of breathing (WOB), and result in abdominal distension. Additionally, the use of BiPAP has been found to reduce the duration of respiratory support. The application of high pressures during CPAP (≥ 9 cmH_2O) has been recently proposed for preterm infants who might need an alternative form of non-invasive support. The use of high CPAP pressures was linked to a higher incidence of pneumothorax, likely due to overexpansion of the lungs in very preterm infants. The failure rate of HFNC was found to be higher than that of NCPAP or NIPPV in preterm infants, despite HFNC being associated with lower incidences of nasal trauma and pneumothorax. The assessment of diaphragmatic kinetics, by measuring the peak velocity of right diaphragmatic excursions (RD-PV), can indicate signs of diaphragmatic fatigue. The ratio of oxygen saturation (SpO_2) to the fraction of inspired oxygen (FiO_2) (SF ratio) was found to be inversely related to RD-PV as recorded using pulsed-wave tissue doppler. Despite possible variations in SpO_2, a low SF ratio and high RD-PV were successful predictors of NCPAP [2] failure in preterm infants with RDS. This observation also implies that the failure of NIV in preterm infants could be linked to sustained high diaphragmatic activity, resulting from the inability to maintain FRC.

Neurally adjusted ventilatory assist

Neurally adjusted ventilatory assist (NAVA) is a form of mechanical ventilation that provides inspiratory assistance in sync with the electronic activity of the diaphragm (EAdi), enabling infants to regulate their own peak inspiratory pressure and tidal volume on a per-breath basis. The EAdi signal is evaluated at the distal esophageal level using electrodes incorporated within a nasogastric tube. The peak EAdi, which correlates with the strength of diaphragmatic contraction, signifies the inspired tidal volume. Persistent diaphragmatic contraction during expiration, known as tonic EAdi, helps maintain the end-expiratory lung volume and functional residual capacity (FRC). In situations of alveolar instability and low compliance, a higher tonic EAdi may be required to preserve the end-expiratory lung volume and FRC. The neural breathing patterns in preterm infants can vary significantly, and ongoing adjustment of NAVA based on the inspiratory time and respiratory rate could aid in better accommodating the infants' needs.

The use of non-invasive ventilation (NIV) [3] with neurally adjusted ventilatory assist (NAVA) is both feasible and well-received in preterm infants, offering physiological advantages such as enhanced synchronization between the patient and the ventilator and a decrease in peak inspiratory pressure (PIP). The application of NIV with NAVA has been observed to facilitate diaphragmatic unloading, potentially leading to a decrease in the work of breathing (WOB). In comparison to nasal intermittent positive pressure ventilation (NIPPV), NAVA has proven to be more effective in reducing instances of bradycardia in infants with very low birth weight.

NAVA has the capability to identify apneas and provide rescue ventilation. If an apnea episode lasts for a specified duration, a pressure-controlled backup ventilation is activated until the resumption of spontaneous ventilation.

Volume guarantee ventilation

For many years, neonates have primarily been ventilated using pressure-limited, time-cycled ventilation. However, the understanding that lung damage from ventilation is more often caused by volume rather than pressure has spurred the creation of new ventilation strategies. One such strategy is volume guarantee, a ventilation mode that automatically modifies the inspiratory pressure to deliver a predetermined tidal volume, taking into account changes in lung compliance, resistance, and the patient's respiratory effort. In this mode, a specific volume of gas is delivered, and the inspiration phase concludes once this volume has been administered.

In ventilated infants, significant variations in tidal volume contribute to respiratory instability, which can result in frequent changes in SpO_2 levels. This method measures each exhaled tidal volume (VTe) and adjusts the PIP for the subsequent inflation to maintain the VTe as constant as possible. Volume guarantee employs a feedback loop to automatically adjust PIP to deliver a set tidal volume, taking into account changes in lung compliance, airway resistance, and the patient's spontaneous respiratory effort [4].

Aerosolized drug delivery

In addition to providing respiratory assistance, pharmacological treatments may be necessary for preterm infants to address comorbidities linked to immature lungs. Aerosol administration is typically done through the nasal route in newborns, as they predominantly breathe through their noses. Compared to full-term infants, preterm infants have a reduced tidal volume, increased respiratory rate and shorter inhalation duration, leading to decreased aerosol delivery and dwell time in the lungs. Furthermore, lung diseases such as RDS can restrict the use of aerosol medication in preterm infants. Interestingly, despite their lower inhaled flow rates, preterm infants show a slightly higher aerosol deposition in the lungs than full-term infants [5].

Drug administration to preterm infants can be achieved either by temporarily disconnecting them from NIV or by incorporating the medication into the NIV circuit, for example, using nebulizers. However, discontinuing respiratory support may not be the best strategy for critically ill patients. Administering aerosolized medication during NIV can provide faster and more effective clinical results without disrupting oxygen and positive pressure delivery. NCPAP has been shown to effectively deliver aerosolized medications.

The delivery of aerosolized surfactant could potentially reduce the need for airway manipulation and is less technically demanding than LISA [6]. However, delivering aerosolized medications during NIV remains a challenge. As a result, nasal cannulas are often used to deliver aerosolized medication during NIV and to provide oxygenation at high gas flow rates. The synchronization of aerosolized medication production with inhalation enhances its lung deposition [7].

The recent advancement of nasal prongs equipped with miniaturized aerosol valves enables the release of medication triggered by inhalation. The effectiveness of aerosol delivery in breath-triggered release was found to be four times greater than that in non-triggered release.

Positive pressure delivery:

The generation of positive pressure during CPAP can be achieved via one of the following methods:

- Modifying the expiratory pressure through the ventilator's expiratory valve.
- Regulating the inspiratory flow using flow drivers or ventilators [8].

These techniques ensure the effective delivery of positive pressure during CPAP.

The Bubble CPAP: A system can generate positive pressure by immersing the distal end of the expiratory tubing in water. The pressure level can be manipulated by changing the depth at which the tube is submerged.

Globally, underwater bubble CPAP systems are the most commonly used, especially in settings with limited resources. Their widespread use can be attributed to their affordability, ease of maintenance, simplicity of operation, and effectiveness comparable to other CPAP devices [9]. Numerous studies have indicated that bubble CPAP can deliver effective positive pressure ventilation as efficiently as, or even more so than, CPAP delivered by a ventilator.

Heart rate

Earlier guidelines from the neonatal resuscitation program (NRP) only necessitated a brief check of the heart rate every 30 seconds to ascertain if it fell within two crucial thresholds (60 and 100 bpm) as outlined in the guidelines. Even when the heart rate is manually auscultated and counted, it can be challenging for the resuscitation leader to quickly detect changes [10]. With the introduction of pulse oximetry for high-risk births, all resuscitation teams are now able to continuously monitor the heart rate, provided the oximeter is operational (Kattwinkel., *et al*. 2010). However, in the initial few minutes of life, the pulse oximeter, while useful, does not offer a dependable heart rate.

ECG, which is based on the heart's electrical activity, is not reliant on circulation and is therefore less influenced by the newborn's transitional state [11]. In studies comparing oximetry with ECG, the early placement of ECG electrodes during newborn resuscitation can provide the resuscitation team with a continuous and reliable audible heart rate sooner. Its usage could enhance the promptness of necessary critical interventions when compared to using pulse oximetry alone (Katheria., *et al*. 2012; Mizumoto., *et al*. 2012).

Considerations of therapies in the neonate with congenital heart disease

The protocol for neonatal resuscitation remains valid even in the context of congenital heart disease (CHD), as stated by Johnson and Ades in 2005, albeit with some modifications. When a neonate presents with hypoxemia that doesn't respond to additional oxygen, heart failure, or shock, it's crucial to focus on both the fundamentals of advanced neonatal life support and ensuring the ductus arteriosus remains open [12]. It's essential to secure a stable airway to facilitate sufficient oxygenation and ventilation in the alveoli. For critically ill neonates with CHD who exhibit intense cyanosis or circulatory failure, intubation should be carried out post-administration of sedatives and neuromuscular blocking agents, if feasible [13]. Measures such as volume resuscitation, inotropic support, and rectification of metabolic acidosis might be necessary to optimize cardiac output and tissue perfusion. It's important to monitor and regulate blood glucose and ionized calcium levels to maintain them within the age-appropriate range. Concurrently, an assessment for sepsis is usually conducted, and provisional antibiotic treatment is started while the evaluation is ongoing.

Bowel distention

A recent development in newborn manual ventilation is the implementation of sustained lung inflation. This technique involves applying a single high pressure to the newborn's lungs to enhance the establishment of the functional residual capacity. This pressure is maintained for a specified duration and then lowered to a standard CPAP level to support spontaneous breathing [14]. While this method is still a subject of debate, emerging evidence indicates that it may reduce the necessity for mechanical ventilation during the initial days of life. Newborns with a congenital diaphragmatic hernia often need positive-pressure ventilation at birth due to respiratory distress accompanied by cyanosis [15]. Administering positive-pressure ventilation with a bag and mask can lead to a significant amount of air entering the upper GI tract, resulting in the distention of a bowel that has herniated into the chest. This bowel distention can further compress the lung and impair respiratory function. Therefore, it is recommended that newborns with a diaphragmatic hernia be intubated promptly in the delivery room if resuscitation is needed. Some healthcare professionals also suggest that these newborns should be paralyzed with a muscle relaxant to prevent bowel distention caused by spontaneous breathing. An orogastric tube should be inserted to remove any air that enters the stomach. The diagnosis of a diaphragmatic hernia is often confirmed through antenatal ultrasound studies and should be considered in any newborn with a scaphoid abdomen, reduced breath sounds on one side, and persistent respiratory distress.

Benefits and complications of delayed cord clamping

"Early" cord clamping typically occurs within the initial 15 - 30 seconds post-birth, while "delayed" cord clamping usually happens around 5 minutes after birth. An alternative method is the "milking" or "stripping" of the cord. Delayed cord clamping (DCC) facilitates the transfer of more blood from the mother's placenta to the baby, potentially increasing the baby's blood volume by 33% (equivalent to 75 - 120 mL of fetal blood). This can enhance iron reserves and brain myelin in infants.

Iron: Iron is essential for newborns to support their rapid growth and development in the first few months of life. The additional blood from delayed cord clamping provides newborns with an extra surge of supplemental iron [16]. This iron boost can have significant long-term benefits and is found to enhance cognitive and motor scores.

Myelin: Recent studies on cord clamping have determined that DCC boosts myelin in the brain. Myelin insulates nerve connections within the brain, and therefore improved myelination contributes to more efficient brain development.

Other advantages of DCC includes: Fewer post-birth transfusions for anemia, elevated average blood pressures and reduced need for inotropic drugs, decreased risk for intraventricular haemorrhage (IVH, all grades), and decreased risk for necrotizing enterocolitis (NEC).

The two main risks associated with delayed cord clamping are hyperbilirubinemia and polycythemia. Hyperbilirubinemia leads to a yellow discoloration of the eyes and skin, known as jaundice. Polycythemia can result in several health issues including difficulty breathing, abnormal blood circulation, and jaundice.

Lotus birth is the practice of leaving the umbilical cord and placenta attached to the newborn until it naturally detaches from the navel. The majority of recent studies and research on delayed cord clamping endorse the conclusion that it provides significant benefits for full-term babies and that the perceived risks are minimal.

Future directions:

a. Further assessment of optimal duration and circumstance (multiples, IUGR, fetal distress).
b. Cord "milking" in the non-vigorous newborn.
c. Timing of uterotonic agents post-birth.

Role of therapeutic hypothermia in neonatal encephalopathy

Peripartum asphyxia is observed in 4 - 5 out of every 1000 live births, with a quarter of these infants showing signs of moderate to severe neonatal encephalopathy (1.5 per 1000). Hypoxic-ischemic encephalopathy (HIE) in neonates is a major contributor to infant mortality and neurodevelopmental impairments. It's also linked to negative outcomes such as cerebral palsy, cognitive impairment, epilepsy, and more, extending beyond the neonatal period. The pathophysiology of HIE involves oxidative stress, failure of mitochondrial energy production, glutaminergic excitotoxicity, and apoptosis. Numerous systematic reviews have shown that therapeutic hypothermia is beneficial for neonates with moderate to severe HIE who would otherwise only have life-supportive care options [17]. Therapeutic hypothermia should be maintained for 72 hours, aiming for a temperature of 33°C to 34°C for whole body cooling, or 34°C to 35°C for selective head cooling. The rewarming process should span 6 to 12 hours, be conducted slowly, and the core temperature should not increase more than 0.5°C/h. Rebound seizures have been observed during the rewarming phase. There's speculation that rapid rewarming could lead to hypotension due to peripheral vasodilation and may also cause electrolyte imbalances (hypoglycemia and hyperkalemia).

Hypothermia results in a roughly 5% reduction in cerebral metabolism for each 1°C decrease in body temperature, which delays anoxic cell depolarization. It alters the cells programmed for apoptosis, leading to their survival.

Cooling reduces mortality without increasing significant disability in survivors. Hypothermia should be implemented in term and late preterm infants with moderate-to-severe hypoxic ischemic encephalopathy if identified before six hours of age.

Despite these findings, hypothermia can potentially cause hypotension and myocardial dysfunction. It triggers a cold diuresis and induces hypovolemia. This is due to increased venous return, stimulation of atrial natriuretic peptide, decreased anti-diuretic hormone levels, and renal tubular dysfunction.

Experimental evidence suggests that the neuroprotective response of hypothermia is influenced by the timing of therapy initiation. It seems wise to initiate therapeutic hypothermia as soon after birth as possible for newborns with moderate to severe HIE.

Benefits of exogenous surfactant for respiratory distress syndrome

Respiratory distress syndrome (RDS) is triggered by a deficiency of surfactant in the lungs of the newborn. The surfactant, primarily phosphatidylcholine, is a fluid produced in the lungs around the 26th week of gestation. As the fetus develops, the production of surfactant in the lungs increases. The key roles of surfactant include: (1) reducing surface tension at the air-liquid interface, thereby preventing the collapse of alveoli at the end of expiration, (2) interacting with pathogens to kill them or prevent their spread, (3) regulating immune responses, (4) minimizing edema formation, (5) enhancing gas exchange, and (6) stabilizing lung volume.

Therapeutically, the administration of exogenous surfactant, also known as surfactant replacement therapy (SRT), is considered for preterm infants showing radiographic (small volume lungs, haziness/ground-glass appearance, air bronchograms [18] and loss of cardiac borders on chest radiographs) and clinical signs of neonatal respiratory distress syndrome. It helps reduce the occurrence of air leak syndromes and does not inhibit the synthesis of endogenous surfactant.

Several SRT procedures are based on the modes of delivery, including INSURE (Intubate-SURfactant-Extubate), LISA (Less Invasive Surfactant Administration), MIST (Minimally Invasive Surfactant Therapy), LMA (Laryngeal Masked Airway administration), and Nebulization (aerosolized surfactant).

The approach to delivering exogenous surfactant has evolved from endotracheal administration of a surfactant bolus during mechanical ventilation to the INSURE procedure. The INSURE procedure involves intubation, surfactant administration, early extubation, and continuous positive airway pressure (CPAP) support. Although INSURE may help reduce complications associated with mechanical ventilation, its success rate is not very high. Sedation is required during INSURE, and the placement of an endotracheal tube may cause pain, stress, or hemodynamic complications. Less Invasive Surfactant Administration (LISA) aims to deliver an adequate amount of surfactant into the trachea via a small-diameter catheter placed orally or nasally beyond the vocal cord. LISA allows infants to breathe spontaneously during surfactant delivery. Infants treated with LISA showed lower rates of BPD, decreased need and duration of respiratory support, and lower rates of CPAP failure compared to other surfactant delivery methods. Some relevant adverse events of LISA include tracheal surfactant reflux, bradycardia, hypoxia, need for intubation, and mucosal bleeding.

The primary functions of surfactant include: (1) reducing surface tension at the air-liquid interface and thus preventing alveolar collapse at end-expiration, (2) interacting with and killing pathogens or preventing their spread, and (3) modulating immune responses. Surfactant normalizes surface tension and decreases transcapillary hydrostatic forces in this lung injury model, thereby reducing edema formation and improving gas exchange.

Surfactant treatment in HFOV preterm infants with RDS leads to a rapid increase and subsequent stabilization of lung volume.

The quest for improved strategies to deliver surfactant in an even gentler manner continues. In this context, surfactant nebulization may emerge as a potential option.

Analgesia and sedation in the NICU

Infants are capable of feeling pain and can benefit from pain relief measures. Repeated exposure to pain in neonates can modify brain neurophysiology, leading to decreased brain maturation and suboptimal motor and cognitive development. Neurons responsible for nociception, or "tissue injury," are present early in gestation, around the 12th week. The neurophysiological pathways for pain afferents reach the cortex between the 20th and 26th weeks of gestational age (GA).

Pain management strategies can be divided into non-pharmacological and pharmacological approaches:

a. Non-pharmacological methods:

- Skin-to-skin contact can reduce pain measures in both term and preterm infants during painful procedures. This method is also effective when provided by a non-mother caregiver.
- Breast-feeding can lower the pain response to needle puncture in term infants.
- Breast milk, administered via a pacifier or syringe, can be as effective as a pharmacological sucrose solution.
- Sensorial stimulation, involving all four elements (tactile, gustatory, auditory, visual), can be more effective than a pharmacological sucrose solution.

b. Pharmacological methods:

- Sucrose is safe and effective for reducing pain from single events in infants as young as 22 weeks GA. It is most effective if administered 2 minutes before the event, with effects lasting approximately 4 minutes.
- Non-opioids, such as paracetamol (acetaminophen), can reduce the overall need for opioids when used for postoperative pain control.
- Opioids are the most common agent for persistent or surgical pain and are recommended for elective intubations.
- Other agents, including ketamine, propofol, methadone, clonidine and dexmedetomidine, have limited or no evidence of efficacy or safety in neonates.
- For short-term, mild to moderate procedures, consider using non-pharmacological strategies, with or without sucrose. For procedural pain relief, treatment with opioids and/or paracetamol is indicated. Premedication can enhance the success of intubation and reduce physiological instability.

CAB vs ABC (C for compressions, A for airway, and B for breathing)

The A-B-C sequence, which prioritizes ventilation as the most crucial step in neonatal resuscitation, was traditionally followed. This is because chest compressions could interfere with effective ventilation. Therefore, it was essential to ensure optimal assisted ventilation before initiating chest compressions. However, the introduction of the C-A-B sequence has altered this approach. In this sequence, chest compressions are started earlier, and ventilation is slightly postponed. Once it's confirmed that the infant is not breathing, 30 immediate compressions are required. The current recommended ratio of chest compressions to breaths is 30:2. Chest compressions aid in maintaining blood flow to vital organs like the heart and brain. The Pediatric Task Force, however, did not endorse the C-A-B sequence, as asphyxia is a leading cause of cardiopulmonary arrest in children, making ventilation a critical component of pediatric CPR.

Until the 2010 update by the AHA International Liaison Committee on Resuscitation (ILCOR), the preferred CPR sequence for infants and children was A-B-C. In 2010, the AHA advocated for the C-A-B sequence to reduce the delay in starting chest compressions and the duration of "no blood flow". The goal was to initiate resuscitation with chest compressions in infants and children. Aligning with adult guidelines was also intended to simplify understanding of the CPR algorithm. ILCOR reviewed the evidence supporting this change, with the most recent update in 2015.

The 2010 AHA guidelines suggested a shift to the C-A-B sequence (Compressions-Airway-Breathing) to minimize the delay in starting chest compressions and decrease the "no blood flow" time.

Artificial intelligence in neonatal resuscitation

Artificial intelligence (AI) can play a significant role in neonatal resuscitation by offering real-time feedback to medical professionals, analyzing vital signs, and predicting outcomes based on various parameters. Here are some ways AI can be beneficial:

1. Decision support: AI algorithms can process real-time physiological data such as heart rate, respiratory rate, temperature, and oxygen saturation levels. This data can assist doctors and nurses in making swift and accurate decisions during neonatal resuscitation. AI-based support systems can provide suggestions for clinical interventions during neonatal resuscitation, such as the initiation of chest compressions, medication administration, or care escalation based on the infant's response to initial interventions. Utilizing AI for decision support can improve outcomes for newborns requiring resuscitative interventions.
2. Simulation training: AI-enabled simulators can create realistic scenarios that replicate various resuscitation situations, such as a newborn with respiratory distress, apnea, or bradycardia. This can help train healthcare workers, including neonatologists, nurses, and respiratory therapists, in neonatal resuscitation techniques. These simulations can enhance skills and readiness for real-life situations, providing healthcare professionals with more practice. Trainers can modify the scenarios to different levels of acuity and difficulty. This training often uses high-fidelity mannequins that simulate newborns, equipped with features such as realistic airways, chest rise and fall, and audible heart and lung sounds. Simulation training aids in practicing essential skills such as newborn condition assessment, establishing effective ventilation with bag mask ventilation or endotracheal tube intubation, chest compressions and circulation management, medication administration, and team communication and coordination. This training is vital for healthcare providers to maintain competency, enhance teamwork, and ultimately improve patient outcomes in neonatal emergencies.
3. Image analysis: AI can analyze medical images, such as X-rays, ultrasound scans, and ECG, EEG readings, to assist in diagnosing conditions that may require resuscitation. For instance, AI can help identify signs of respiratory distress syndrome, heart conditions, congenital abnormalities, meconium aspiration syndrome, and pneumothorax.
4. Predictive analysis: AI algorithms can analyze large datasets of neonatal health records to identify patterns and predict which infants are at a higher risk of requiring resuscitation. AI-powered tools can automate documentation tasks and streamline workflow processes during neonatal resuscitation, allowing healthcare providers to focus more on patient care and decision-making. This early identification can help allocate resources more effectively and intervene proactively. This also aids in epidemiological studies and helps to identify various risk factors in the newborn in a specific group of people or country. Hence, preventive measures can be taken in these groups.
5. Remote monitoring: AI-powered monitoring systems can track vital signs remotely, allowing doctors or healthcare providers to intervene quickly if a newborn requires resuscitation, even if they are not physically present in the same location. This is achieved by placing cameras and microphones in the NICU or delivery room, along with secure communication channels for real-time interaction between the remote provider and the resuscitation team.

6. Quality assurance: AI can analyze video recordings of neonatal resuscitation procedures to provide feedback on the quality of care provided, helping healthcare providers improve their techniques and adherence to guidelines. Several key aspects of quality assurance for AI in neonatal resuscitation are algorithm development, validation and regulatory compliance, clinical integration and human oversight, continuous monitoring and updating, transparency and explainability, data privacy, and security [19].

While AI can significantly assist in many aspects of neonatal resuscitation, it cannot fully replace human healthcare providers. AI cannot replicate the complex judgment, intuition, and empathy that human healthcare providers bring to patient care. In neonates who need resuscitation, individualized care is crucial. Healthcare workers must assess the unique needs and responses of each newborn and intervene accordingly. Additionally, effective teamwork with communication and coordination among the resuscitation team is important, which AI alone cannot replicate. AI may fail to understand the broader aspects of a patient's condition, such as social, cultural, and ethical considerations, which are integral parts of providing holistic care.

Conclusion

There are recognized knowledge gaps in the optimal approach and treatment for newborns requiring intensive resuscitation. The focus should be on enhancing ventilation while preventing lung damage and hyperoxemia. Although sustained inflations may be beneficial, the best methods to provide positive pressure ventilation to establish and maintain a functional residual capacity, and the optimal way to assess ventilation, are yet to be determined. In the uncommon situation where chest compressions and medications are required to achieve effective return of spontaneous circulation, further research is needed to determine the optimal compression to ventilation ratio, timing, route, dose and type of vasopressor.

Simple interventions such as delayed or physiological cord clamping, drying and stimulating newborns, and bag-mask ventilation can significantly reduce mortality and morbidity associated with birth asphyxia globally.

ECG is quicker in assessing heart rate at birth and more reliable in detecting changes in heart rate compared to other recommended technologies. However, reliance on ECG alone is not advised in current practice. While innovative technologies can aid in heart rate assessment, there are currently no studies validating their clinical efficacy during neonatal resuscitation.

Emerging forms of respiratory support, designed to enhance synchronization of breaths between the patient and the ventilator, are under development. It will be crucial to consider and evaluate their use in preterm infants. Neurally Adjusted Ventilatory Assist (NAVA) is an innovative form of non-invasive ventilation designed to improve synchronization. It operates by detecting the electrical activity of the diaphragm (via an electrode placed in the esophagus).

Optimal ventilatory settings and weaning strategies of non-invasive ventilation are needed to prevent failure of NIV and the need for intubation and mechanical ventilation.

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