Seminars in Fetal and Neonatal Medicine 24 (2019) 101039

Contents lists available at ScienceDirect

Seminars in Fetal and Neonatal Medicine

journal homepage: www.elsevier.com/locate/siny

Delivery room emergencies: Respiratory emergencies in the DR

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ARTICLE INFO

Keywords:
Infant
Newborn
Positive pressure ventilation
Delivery room
Resuscitation

ABSTRACT

The majority of newborns transition to extra uterine life without support. However, respiratory emergencies in the delivery room are a common occurrence. Whilst some situations are predictable e.g. the anticipated birth of an extremely preterm infant, others are less so. In this chapter we address the most frequent scenarios that result in delivery room respiratory emergencies and discuss the latest recommendations for their management. We outline the need for a trained resuscitation team and appropriate equipment to provide respiratory support at every birth. We address the basic care that all infants should receive, the detailed application of non–invasive ventilation and the use of advanced airway techniques. We discuss the unique challenges presented by extreme prematurity including umbilical cord management, use of supplemental oxygen, initial modes of respiratory support and surfactant delivery. We will explore optimal techniques in the management of infants with lung hypoplasia, pneumothorax and meconium aspiration.

1. Why are there respiratory emergencies in the delivery room (DR)?

Most newborn infants transition smoothly to extra uterine life. However, the need for respiratory support immediately after birth remains a relatively frequent neonatal emergency. Up to 5% of term-born infants need help to establish breathing [1], and although many very preterm infants have good initial respiratory efforts [2], the most premature infants are likely to need assistance to support and maintain their efforts [2]. The majority of delivery room respiratory emergencies therefore occur when infants don't breathe (mostly asphyxiated term infants), and in infants who cannot breathe sufficiently, mostly very preterm infants. Other emergencies occur in infants whose lungs are hypoplastic, who become unexpectedly unwell in the DR e.g. those who develop a pneumothorax or are born through meconium-stained amniotic fluid, and those who have anatomical anomalies (see Chapter *).

The key to successfully establishing breathing after birth is lung aeration. Inspiration, followed by prolonged expiration through a partly closed glottis drives lung fluid distally [3], the lungs aerate, functional residual capacity is established, pulmonary vascular resistance falls and pulmonary blood flow increases, perfusing the myocardium and increasing cardiac output [3]. Transition is facilitated by delaying cord clamping until after lung aeration: this delay stabilizes cardiac output and heart rate, maintaining left ventricular preload whilst the lungs aerate [4]. This sequence underlines why newborn resuscitation guidelines are heavily focused on respiratory support; when lung aeration is successful, gas exchange quickly results in a rising heart rate, meaning that for most newborn infants respiratory support is only briefly needed [5].

2. How do we recognize those in need of respiratory support in the DR?

Many DR respiratory emergencies can be predicted. The likelihood of needing respiratory support at birth increases in the presence of risk factors including placental abruption, cord prolapse or lower gestational age [6]. Nevertheless, respiratory emergencies frequently occur without clear antecedent events.

After birth, warming, drying, stimulating and opening the airway should occur [1] whilst assessments are made of tone, color, responsiveness, respiratory effort and heart rate (a key early sign of an infant's condition). Those with good tone and heart rate are unlikely to be severely hypoxic. In contrast, a pale, floppy baby who is apneic or bradycardic urgently requires positive pressure ventilation, ideally within 60 s [1]; to maximize the likelihood of success. Hence, positive pressure ventilation is the most important skill in neonatal resuscitation; all clinicians involved in stabilization at birth must be competent in the technique.

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https://doi.org/10.1016/j.siny.2019.101039

As respiratory emergencies are unpredictable, every maternity center should have a fully trained resuscitation team and equipment for positive pressure ventilation immediately available. All healthcare providers involved with newborns must be regularly trained in newborn resuscitation. As knowledge and skills quickly decline [7], short, regular, low fidelity sessions are needed for optimal skill retention [8]. Team training is critical; poor teamwork and communication are the commonest causes of potentially preventable deaths in the DR [9], and team simulation training improves resuscitation outcomes [10]. Resuscitation team members need defined roles and an identified leader who directs, delegates and maintains situational awareness. A pre-resuscitation briefing that summarizes the scenario, identifies the roles, and plans the response should occur. A standardized pre-birth checklist enhances this preparation [11].

3. Practical management of respiratory emergencies

3.1. Monitoring, thermoregulation, stimulation and supplemental oxygen

During respiratory emergencies, monitoring of heart rate (by auscultation) and breathing effort should be undertaken. Where advanced technologies are available, pulse oximetry and electrocardiography are recommended [1]. Normothermia should be maintained, particularly in very preterm infants [12] in whom hypothermia is associated with increased mortality. A warmed room, radiant heat, and plastic wraps and hats are recommended [13]. Use of heated, humidified resuscitation gases should be considered [14]. Positioning, drying and stimulating is often sufficient to initiate spontaneous breathing in term infants, but if not, additional stimulation including rubbing the back, chest or abdomen, or flicking the foot may be helpful. These interventions are often delayed or omitted [15] and experts have suggested that, on a global scale, immediate neonatal assessment with stimulation could reduce peri-partum deaths by 10% [16].

When there is an inadequate response, positive pressure ventilation (PPV) is required without delay. For term infants, resuscitation should commence in 21% oxygen, except if cardiac compressions are required when 100% oxygen is suggested [1]. For preterm infants, supplemental oxygen is probably necessary [1]; 30% oxygen is frequently recommended although evidence is inconclusive [17]. Whatever oxygen concentration is initiated, this should be titrated against targets based on the rising saturations of normal term infants in the minutes following birth [18].

3.2. Respiratory support

Newborns who fail to respond to basic measures require positive pressure support. This is typically applied using a facemask or nasal prong(s) and a pressure-generating device. When some respiratory effort is present, continuous positive airway pressure (CPAP) may be sufficient to support lung aeration and functional residual capacity. However, an apneic or bradycardic infant requires positive pressure ventilation (PPV).

3.2.1. Generating positive pressure

Several devices can be used to deliver PPV. These vary in terms of their cost, need for a gas supply and ability to deliver PEEP/CPAP. Self-inflating bags (SIBs) are widely available and can be used without a gas supply, making them the most useful device in resource-limited settings. Delivered pressures and volumes vary with how much the bag is squeezed, although the latest “upright” designs of SIB provide more consistent volumes [19]. SIBs can be fitted with attachments that allow them to deliver PEEP, but not CPAP. Flow-inflating bags (FIBs) need a continuous gas supply to re-expand, again delivered pressures and volumes vary depending on how much the bag is squeezed, and FIBs may be more difficult to use than SIBs [20]. Attachments can be used to support PEEP delivery, but consistent PEEP is difficult to achieve. Neither device is optimal for preterm infants who need CPAP and/or PEEP [21].

The T-piece device is a popular alternative. It is a flow-controlled system, requiring a gas supply, but with the advantage of being able to set desired pressures. T-pieces accurately deliver peak inspiratory pressure (PIP), PEEP and CPAP, with less tidal volume variability than other devices [22], and they are preferred by clinicians [23]. However, studies have not shown important differences in outcomes between devices [24]. If either a T-piece or FIB is preferred, a back-up SIB should be available in case of failure of gas supply. Safe and effective ventilation during neonatal resuscitation depends on delivery of sufficient tidal volume to exchange oxygen and carbon dioxide without causing lung damage through volutrauma. However, none of these devices measure tidal volume. Although it is feasible to monitor volume delivery in the DR [25], the devices are yet to be tested in large randomized controlled trials (RCTs). Neonatal ventilators can provide accurate pressure and volume delivery, as well as CPAP/PEEP [26], but they are expensive and require training and practice to use correctly.

3.2.2. Pressure, volume and timing of mask ventilation

When respiratory efforts are either absent or inadequate, PPV is required for clearance of lung liquid and aeration. In term infants, the focus is on rapid assessment with brief stimulation, followed quickly by lung aeration using positive pressure in room air, supported by PEEP where available.

PPV is typically delivered via a circular mask covering the mouth and nose. During PPV, inflation rates of 40–60 per minute are recommended, with duration of each inflation timed to reflect spontaneous inspiratory times of newborns (about 0.3 s) [27]. Effective mask ventilation requires a good seal between the mask and the infant's face [28] whilst minimizing mask leak and airway obstruction. Effective mask technique is difficult to achieve and maintain [20]. Masks of the correct size and shape are needed, along with correct placement and hold. Using a mask and T-piece, operators typically have 40–60% leak [28]; when leak rises further, delivered pressures and volumes fall [29]. Neither peak pressure nor chest rise are good indicators of delivered volume [30]. Colorimetric carbon dioxide detectors may be used to confirm volume delivery and determine effectiveness of ventilation [31], responding before improvements in heart rate and oxygen saturations [32]. Concern over mask leak can result in excessive mask pressure being applied [33], distorting the nose, obstructing the airway [29, 34] and impeding effective mask ventilation. Simply placing a mask over the face can result in reflex apnea requiring escalation in resuscitative efforts. This effect has driven the search for alternative interfaces, such as a nasally placed cut-down endotracheal tube [35], short bi-nasal prongs [36] and nasal cannulae [37, 38]. However, none of these have been shown to be superior to a facemask in an RCT.

During mask ventilation, tidal volume delivery depends on multiple factors; spontaneous breathing effort, glottic opening, lung compliance, applied pressures, mask leak and airway obstruction. This results in delivery of variable tidal volumes, often much higher than volumes generated during spontaneous breathing [39], risking lung and brain injury [40]. Guidelines recommend starting with peak pressures of 20–30 cm H_2O [1], as these typically produce adequate, but not excessive, tidal volumes. PEEP is routinely provided for term and preterm infants during resuscitation despite the lack of strong clinical evidence of its effectiveness in the DR. There is convincing animal evidence of benefit for PEEP in establishing functional residual capacity [21] meaning that it is recommended for preterm infants and reasonable for term infants [1]. A single, standard level of PEEP is unlikely to suit all preterm infants, those with the highest oxygen requirements may require higher PEEP.

During mask ventilation, if chest wall movement is poor or absent, steps need to be taken to ensure optimal mask size, positioning and hold, and PIP may need to be increased [41]. Once the heart rate is above 100 beats/minute and spontaneous breathing is established, PPV

can be ceased in term infants, or converted to mask CPAP in preterm infants.

3.2.3. Advanced airway support

Infants who do not respond to PPV (heart rate < 100 beats/minute after 30 s of effective mask ventilation), may require endotracheal intubation. Other indications for intubation include persistent hypoxia despite mask ventilation, or a prolonged need for mask ventilation [1]. The decision to intubate may vary according to gestational age, respiratory effort, and experience of the resuscitator.

Neonatal intubation is a technically challenging procedure. With changes in practice, fewer infants are being intubated. It is increasingly difficult to train junior clinicians to perform the task, and skills are declining. Experienced operators successfully intubate at the first attempt more than 85% of the time, whereas junior trainees succeed less than half the time [42], frequently taking longer than the recommended 30 s [42]. Rates of successful intubation can be improved by the use of videolaryngoscopy supervised by an experienced intubator [43].

Alternative airway adjuncts, such as a laryngeal mask airway (LMA), may be useful, particularly for less experienced clinicians. LMAs are quick and easy to insert [44]; even for novices success rates are high. LMAs are commonly used in neonatal anesthesia and have been trialled successfully at birth in settings where resources, training and experience are limited [45]. Guidelines recommend that LMAs should be available in all birth settings and neonatal resuscitators should be trained in their use. They may be life-saving when mask ventilation is unsuccessful and endotracheal intubation is not possible [1]. However, there are a limited range of LMA sizes available, and their use is not usually possible in infants below 1500 g, or 31 weeks' gestation. Whichever method is used to achieve ventilation, lung aeration must be established before commencement of chest compressions, as compressions will be ineffective without lung aeration.

4. Special situations

4.1. The extremely preterm infant

Extremely preterm infants born < 28 weeks' gestation represent a unique and high-risk patient group. Optimal antenatal care, including antenatal corticosteroids and magnesium sulfate, tocolysis, and transfer to a tertiary-level center when possible improves outcome [46]. Extremely preterm infants have immature, surfactant-deplete lungs and almost universally require some respiratory support, both for apnea and for respiratory distress syndrome (RDS); they much more frequently require advanced resuscitation interventions such as endotracheal intubation compared with more mature infants. Their stabilization in the DR requires careful and tailored management that aims to minimize lung injury and optimize longer-term outcomes.

4.1.1. Umbilical cord clamping

The benefits of delayed cord clamping (DCC) in mature infants are well documented, and these benefits may also apply to extremely preterm infants. Although no difference was seen in a recent large trial of DCC in infants born < 30 weeks' gestation [47], a recent meta-analysis of trials comparing DCC with immediate clamping showed a significant reduction in mortality before hospital discharge when DCC was used, including in the extremely preterm subgroup [48]. DCC in extremely preterm infants has additional challenges, including access to the infant to provide respiratory support, and temperature control. Specialized equipment has been developed and tested to make DCC in these infants feasible [49], and is under investigation. Currently, clinicians wishing to provide DCC to this group typically only do so if the infant is assessed as not requiring immediate respiratory intervention. Umbilical cord 'milking' is another technique recently investigated [50]. However, an association with intra-ventricular hemorrhage means it currently cannot be recommended [51].

4.1.2. Apnea

Most extremely preterm infants will demonstrate respiratory effort soon after birth [2]. If not, like more mature infants, they should be stimulated. However, in the rush to initiate respiratory support this step is sometimes forgotten in the smallest infants [52]. Caffeine is a respiratory stimulant routinely used to treat extremely preterm infants in the neonatal unit, based on extensive evidence of short- and long-term benefits [53, 54]. Caffeine in the DR is feasible and may be beneficial [55], but more research is required.

4.1.3. Supplemental oxygen

In the minutes after the birth of an extremely preterm infant, clinicians must balance the need for adequate oxygenation with the avoidance of hyperoxic damage to developing organs such as the brain and retina. Titrating supplemental oxygen against peripheral oxygen saturations is recommended, although data on the optimal targets are limited in this population. In extremely preterm infants, resuscitation with 21% oxygen may be disadvantageous compared with using 100% oxygen in terms of poorer recovery from bradycardia and higher mortality [56]. However, no significant differences were seen in a meta-analysis of RCTs comparing lower (≤30%) with higher (≥60%) oxygen for infants born < 29 weeks' gestation [57]. Guidelines currently recommend commencing extremely preterm infants in some (21–30%) oxygen,[1 46] indicating a preference to minimize exposure to supplemental oxygen in the absence of convincing evidence of benefit from higher concentrations.

4.1.4. Respiratory support

It has been hypothesized that quickly establishing adequate lung volume in the DR by using sustained inflations may reduce lung injury in extremely preterm infants. Whilst early trials showed promising improvements in short-term outcomes [58], a large, recent RCT did not support this and was stopped early due to an increase in early deaths (within 48 h of birth) in the intervention group [59].

Historically, extremely preterm infants were routinely managed with early endotracheal intubation in the DR. However, meta-analysis of the four large RCTs comparing early nasal CPAP with routine endotracheal intubation [60] found a borderline reduction in BPD in the CPAP group, no difference in mortality, and a significant benefit for the combined outcome of death or BPD at 36 weeks' PMA in the CPAP group. Given these findings, clinicians increasingly attempt to stabilize extremely preterm infants without an endotracheal tube.

4.1.5. Surfactant

Early respiratory management of extremely preterm infants aims to avoid intubation and ventilation, whilst identifying the need for surfactant and administering it as early as possible when required. Early surfactant administration decreases the risk of mortality, BPD, and pulmonary air leaks [61], and the only benefit to delaying surfactant administration is to avoid intubation. Requirement for surfactant in the DR is assessed clinically, using oxygen requirement, level of respiratory distress and response to resuscitation as guides. Point-of-care lung ultrasound and rapid quantification of surfactant in gastric aspirates to assess the need for surfactant remain under investigation.

Endotracheal surfactant administration requires intubation skills and availability of mechanical ventilation. Surfactant administration without intubation (less- or minimally-invasive surfactant administration), given via a thin catheter during spontaneously breathing on CPAP, has been developed and tested. Meta-analysis of RCTs of the technique suggest that it is superior to endotracheal administration; reducing the need for mechanical ventilation and the combined outcome of death or BPD [62]. These less-invasive techniques still require laryngoscopy and debate continues as to the appropriate analgesia required to avoid distress and maintain physiological stability [63]. Techniques that avoid laryngoscopy, such as pharyngeal instillation [64], nebulisation [65], and administration via an LMA [66], are under

investigation but none are yet ready for clinical use.

4.2. Pneumothorax

Leakage of air following rupture of overdistended alveoli tracks to the pleura causing pneumothorax. Although the condition may occur in healthy term infants receiving no resuscitation, it is more commonly associated with other pathologies including meconium aspiration syndrome, surfactant deficiency and pulmonary hypoplasia, usually in conjunction with PPV. In the DR, pneumothorax may present as a sudden deterioration in an infant's condition manifested by hypoxemia, poor perfusion, reduced breath sounds and asymmetry or overdistension of the chest wall. Rapid diagnosis using transillumination, and confirmation with a chest x-ray prior to drainage is ideal but when an infant is unstable, treatment should proceed immediately. Point-of-care lung ultrasound has recently been demonstrated to reliably diagnose pneumothorax in the NICU [67] and may be applicable in the DR. Conventional treatment involves placement of a chest tube, positioned anterior to the affected lung, this can be challenging in the DR where asepsis may be harder to attain. Recent data show that in the NICU initial needle aspiration adequately treats pneumothorax in 30% of cases [68]. The applicability of this technique in the DR is untested.

4.3. Meconium stained amniotic fluid (MSAF)

MSAF is an indication of fetal distress and a risk factor for the need for respiratory support after birth. Therefore, a trained resuscitator with intubation skills should attend births complicated by MSAF. The approach to MSAF has become less aggressive over the past two decades. Routine oropharyngeal or tracheal suctioning of vigorous infants born through MSAF is not beneficial [69, 70]. The question of how best to manage the non-vigorous infant remains controversial. A small RCT showed no reduction in incidence of meconium aspiration syndrome or other adverse outcomes with routine intubation and tracheal suction [71]. This lack of effectiveness, and the potential delay in providing mask ventilation, led the International Liaison Committee on Resuscitation to state that there is insufficient evidence to support routine suctioning of meconium in non-vigorous infants born through MSAF [1], but that large RCTs are needed to better answer this important question.

4.4. Lung hypoplasia

A variety of conditions are associated with poor lung growth including congenital diaphragmatic hernia, dealt with in Chapter *. Lack of lung fluid during fetal development, such as from prolonged preterm rupture of the membranes (PPROM) with reduced amniotic fluid volume leads to immature, hypoplastic lungs [72]. Outcomes following PPROM have improved over the last 20 years as surfactant, inhaled nitric oxide to manage pulmonary hypertension, high frequency oscillatory ventilation and cardiovascular support agents have been more consistently offered. Survival rates have improved substantially, up to 90% in recent reports [73]. Therefore, full resuscitation efforts in the DR should be initiated, directed at minimizing further lung damage. Hypoplastic lungs often have normal compliance. Therefore, the use of low distending pressures to avoid lung damage and cardiovascular compromise is appropriate [74]. Pneumothorax is more frequent and a sudden deterioration should alert clinicians to look for and treat this potential complication. Once stabilized, consideration should be given to early detection and treatment of surfactant deficiency and pulmonary hypertension.

5. Summary

Most newborn infants do not require intervention to successfully transition to extra uterine life. However, on a global scale, efficient stabilization and resuscitation of all newborn infants who need help to establish breathing at birth, particularly asphyxiated term infants would save many lives. The provision of effective ventilation in the DR is key to achieving this goal.

Practice points

- DR respiratory emergencies are common and not always predictable.
- All centers where births occur should have staff who are trained and prepared to deliver immediate respiratory support.
- For all infants, focusing on lung inflation with timely and continuous respiratory support is critical.
- In term infants, resuscitation should commence using air; the commonest pathologies to consider are asphyxia, meconium aspiration, lung hypoplasia and pneumothorax.

Research directions

- The optimal concentration of oxygen and target oxygen saturation levels during resuscitation of preterm infants need to be established.
- The role of commencing respiratory support before umbilical cord clamping needs evaluation.
- The optimal training regimes to achieve and maintain resuscitation skills need to be identified.

Declaration of competing interest

Louise Owen: 1159444, Brett Manley: 1159225 and Peter Davis: 1157782 and 1113902 are all supported by grants from the Australian National Health and Medical Research Council.

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