REVIEW

Advances in neonatal resuscitation for the obstetric anesthesiologist

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Purpose of review
This review provides an updated overview of neonatal resuscitation practices relevant to obstetric anesthesiologists, with a focus on term and late preterm neonates (>34 weeks' gestation). Key topics include umbilical cord management, temperature regulation, airway strategies, and pharmacological interventions, emphasizing evidence-based approaches.

Recent findings
Delayed cord clamping enhances neonatal outcomes, including improved blood volume and oxygenation. Positive pressure ventilation remains the cornerstone of neonatal resuscitation, with early initiation reducing mortality. Supraglottic airways are emerging as effective alternatives to face masks. Advances in epinephrine administration and dosing show promise, though evidence gaps persist. Simulation-based training, telemedicine, and artificial intelligence are advancing skill retention and resuscitation support.

Summary
Recent advancements in neonatal resuscitation focus on precision in ventilation, thermoregulation, and airway management. Obstetric anesthesiologists play a critical role in neonatal emergencies, underscoring the need for continuous training and the integration of emerging technologies like artificial intelligence to optimize neonatal outcomes.

Keywords
airway management, neonatal resuscitation, temperature regulation, umbilical cord management

INTRODUCTION

Neonatal resuscitation is a critical intervention ensuring a successful transition from intrauterine to extrauterine life. This process differs from other forms of resuscitation due to the physiological shift from the fluid-filled womb to the air-filled environment of the delivery room. While most neonates adapt without assistance, approximately 10% require support to initiate breathing at birth [1]. In these cases, ventilation is paramount, with anesthesiologists uniquely positioned to provide timely and evidence-based care in neonatal emergencies.

This review focuses on advancements in neonatal resuscitation for term and late preterm neonates (>34 weeks' gestation), including cord clamping, temperature management, ventilatory support, and airway strategies.

UMBILICAL CORD MANAGEMENT

Historically, early cord clamping (ECC), performed immediately after birth, was standard practice to expedite neonatal assessment. Delayed cord clamping (DCC), defined as clamping more than 60 s after birth or until cord pulsation ceases, however, has gained prominence for improving neonatal physiology, including increased blood volume, iron stores, and better respiratory outcomes.

Ideally performed after lung aeration, DCC is recommended by major organizations like the American Heart Association and the European Resuscitation Council [2,3]. DCC improves neonatal outcomes, including increased hemoglobin levels and blood volume, and reduces anemia

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KEY POINTS

- DCC is standard practice for neonates in good condition.
- Maintaining neonatal body temperature within 36.5–37.5 °C is crucial.
- PPV is foundational in neonatal resuscitation.
- Supraglottic airways are effective for ventilation.
- Simulation-based training enhances skill retention and protocol adherence.

risk, particularly in preterm infants, with benefits extending to term newborns [4–6▪]. Additionally, Satar *et al*. demonstrated that 180-s DCC enhances cerebral oxygenation and pulmonary flow velocity [7]. The Milking in Nonvigorous Infants (MINVI) trial found no long-term neurodevelopmental risks associated with DCC [8]. ECC remains appropriate in cases where placental transfusion is unlikely, such as maternal hemorrhage or placental abruption.

While evidence supporting DCC during resuscitation is limited, ongoing trials may clarify its role [9▪]. Intact cord resuscitation, which preserves placental circulation during stabilization, benefits nonvigorous neonates by combining transfusion and resuscitation [10].

TEMPERATURE MANAGEMENT

Newborns are highly vulnerable to temperature loss after birth, with both hypothermia and hyperthermia being linked to increased morbidity and mortality [11]. WHO and International Liaison Committee on Resuscitation (ILCOR) recommend maintaining neonatal body core temperature within the range of 36.5–37.5 °C, emphasizing prevention strategies [12].

Temperature should be measured and monitored as a quality metric. Radiant warmers, warm blankets, plastic wraps, hats, and heated, humidified gases are effective, particularly for neonates <32 weeks' gestation (Fig. 1). For resuscitation, these warming adjuncts, either individually or in combination, reduce the risk of hypothermia. In resource-limited settings, clean plastic bags can help prevent hypothermia. Hyperthermia (>38.0 °C) should always be avoided. 'Golden hour protocols', emphasizing thermoregulation, have improved outcomes for the term and preterm infants [13▪▪].

TACTILE STIMULATION AND DRYING

Newborns with effective breathing should be placed skin-to-skin with their parents, requiring no routine tactile stimulation or suctioning, even in meconium-stained amniotic fluid [14]. For apnea or ineffective breathing, gentle drying and stimulation (e.g. gently rubbing the back and soles of their feet) may initiate respiratory effort with potential benefits observed in preterm infants, particularly when used during or after positive pressure ventilation (PPV) [15].

VENTILATORY SUPPORT

A comprehensive resuscitation equipment checklist (Table 1) ensures readiness and minimizes delays in life-saving interventions. Ventilation is the cornerstone of neonatal resuscitation, addressing apnea as the primary cause of bradycardia and cardiac arrest.

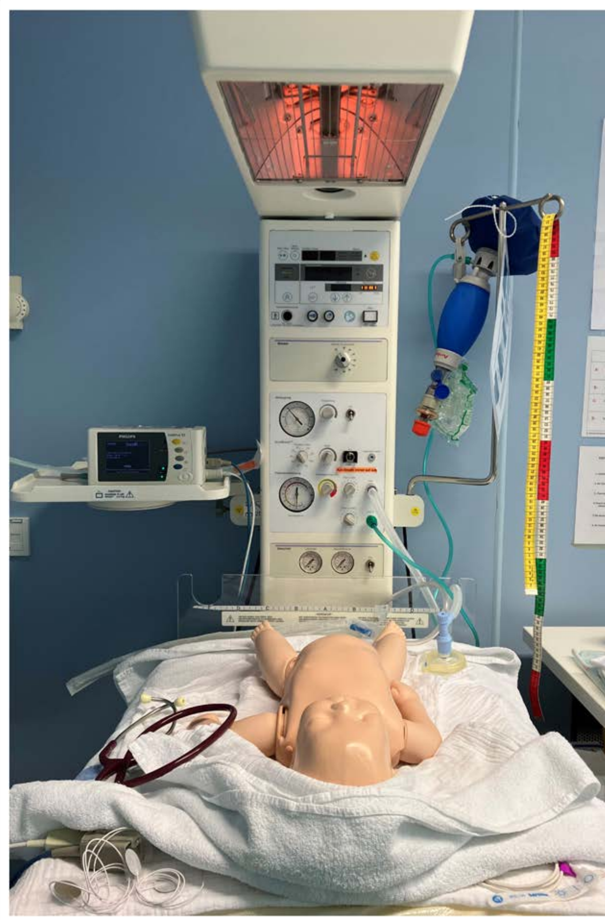

FIGURE 1. Neonatal resuscitation unit setup with manikin for simulation training. Neonatal resuscitation unit with radiant warmer, ventilation bag, face mask, and monitoring equipment shown with a simulation manikin.

Table 1. Equipment checklist for neonatal resuscitation

Category	Equipment (all items should be latex free)	Purpose/comments
Thermal management	Preheated warmer, warm towels/blankets	Prevents hypothermia
	Temperature sensor and cover	Monitor neonatal temperature
	Head cover, plastic bag/wrap (for preterm <32 weeks)	Reduces heat loss
Monitoring	Stethoscope	Assess heart rate and breath sounds
	ECG leads and monitor	Continuous cardiac monitoring
	Pulse oximeter and sensor	Monitor oxygen saturation levels
Airway clearance	Suction catheter (10/12 Fr)	Clears secretions from the airway
	Meconium aspirator	Clears secretions from the airway
Ventilation support	Flowmeter, oxygen blender	Controls oxygen concentration
	T-piece, self-inflating or flow-inflating bag	Provides positive-pressure ventilation (PPV)
	Face masks (various sizes)	Ensures proper fit for effective ventilation
	Gastric tube (8/10 Fr)	Gastric decompression, nasal continuous positive airway pressure (CPAP) support
Advanced airway	Video laryngoscope, laryngoscope blades (Miller 00, 0, 1)	Facilitates intubation
	Tracheal tubes (sizes 2.5, 3, 3.5 mm)	Appropriate tube sizing for neonatal airway
	End-tidal CO_2 detector	Confirms tracheal tube placement
	Supraglottic airway (laryngeal masks)	Alternative airway for difficult/failed intubations
Circulation and medications	Epinephrine (100 mcg/ml)	First-line medication in neonatal resuscitation
	Normal saline	Volume resuscitation
	Umbilical catheter set (5 Fr), intravenous cannulas (24 G)	Rapid vascular access
	Intraosseous access kit (if available)	Alternative access
	Saline flushes	Maintains patency of vascular access
Additional items	Syringes (various sizes), stopcock, scissors, tape, clock with a second timer, resuscitation record sheet	Essential for procedural support, time tracking, and documentation

Modified from Kariuki *et al.* [16].

Current guidelines recommend PPV as the first-line intervention, rather than starting with chest compressions [2]. Most newborns breathe spontaneously within 30–60 s of life, occasionally requiring drying and tactile stimulation. If apnea or bradycardia (heart rate <100/min) persists beyond 60 s, PPV should be initiated at a rate of 40–60 breaths per minute. Delays in initiating PPV increase mortality by 16% for every 30-s delay [17].

PPV supports the transition from fluid-filled fetal lungs to air-filled neonatal lungs, establishing functional residual capacity (FRC) for effective gas exchange. Inspiratory times of 1 s are recommended, as prolonged times (>10 s) can cause harm. Peak inspiratory pressure (PIP) should not exceed 30 cm H_2O in term newborns and should be reduced to 20–25 cm H_2O in preterms to avoid excessive tidal volumes. Ventilation efficacy is best measured by heart rate increases, as chest expansion can be unreliable. While CO_2 detectors or capnography may enhance monitoring, their routine use is not yet recommended [18].

Ventilation devices, including self-inflating bags, flow-inflating bags, or neonatal T-piece resuscitators, are essential. The T-piece provides consistent inflations with blended air and oxygen, ensuring precise PIP delivery and minimizing excessive tidal volumes [19▪▪].

Positive end-expiratory pressure of 5 cm H_2O is commonly used to enhance FRC, maintain lung volume, and improve oxygenation, with evidence suggesting reduced mortality in preterm neonates [20].

OXYGEN ADMINISTRATION

Following birth, the neonatal respiratory system transitions from a low-oxygen intrauterine environment to ambient air (21% oxygen), with SpO_2 levels rising from ~60% at 1 min to ~85% at 5 min. Continuous positive airway pressure or PPV should begin with ambient air, guided by pulse oximetry to monitor SpO_2 and adjust oxygen as needed [21]. Supplemental oxygen may be administered during resuscitation to prevent hypoxemia while avoiding the potential harms of hyperoxia [22]. Initiating resuscitation with 21% oxygen, guided by pulse oximetry, reduces short-term mortality compared with 100% oxygen. During chest compressions, FiO_2 should be increased to 100% to optimize oxygen delivery [23].

AIRWAY MANAGEMENT

Effective neonatal airway management is crucial during resuscitation, requiring knowledge of proper device use and precise techniques.

Current guidelines discourage routine suctioning, even in cases of meconium-stained amniotic fluid, as it may delay the initiation of ventilation [24]. Instead, ventilation should begin promptly, with suctioning reserved for visible airway obstructions or failed ventilation attempts. Studies show no clinical benefit from routine suctioning and highlight risks such as desaturations and bradycardia. Suctioning is advised only for visible obstructions or persistent impairment during PPV [25,26].

A properly sized face mask (FM) should effectively cover the newborn's nose and mouth [27]. Successful ventilation depends on correct technique, as issues like mask leakage, airway obstruction, and gastric inflation can hinder efficiency. If ventilation fails, alternative airway strategies should be considered. Innovations like volume-targeted PPV show potential in reducing tidal volume variability but require further validation for practical application [28]. Training is essential, as inexperienced providers often apply uneven forces during mask ventilation, reducing effectiveness, particularly with self-inflating bags [29▪].

ILCOR guidelines recommend supraglottic airways, such as laryngeal masks (LMs), as a primary tool for PPV in newborns ≥34 weeks' gestation. Adoption, however, remains limited. A 2023 survey revealed that 26% of delivery rooms lack LMs, with providers citing limited experience and low confidence in their use [30▪▪].

Recent studies highlight their efficacy, including safe use in neonates weighing >2000 g and cases of craniofacial abnormalities [31▪,32]. A 2022 review found LMs to be more effective than FMs in achieving adequate heart rates with reduced PPV failure and intubation rates [33]. Advanced models for newborns and preterms offer intubation compatibility and gastric channels for decompression [16]. Encouraging their use aligns with anesthesiologists' expertise in supraglottic devices.

Endotracheal intubation, a core skill for anesthesiologists, is infrequently performed in neonates and often managed by neonatologists, limiting experience. Neonates' unique anatomy – smaller airways, larger tongues, and anterior larynges – makes intubation challenging, with first-attempt success rates below 50% [34]. Precise airway management is essential to avoid rapid desaturation, esophageal intubation, and trauma [35▪▪].

In emergencies, oral intubation is preferred due to its efficiency and lower trauma risk, but the choice between oral and nasal routes depends on institutional practices and provider expertise. Videolaryngoscopy improves first-attempt success rates, particularly in emergencies, though its use in neonatal populations by anesthesiologists warrants further investigation [36▪▪].

VASCULAR ACCESS

Emergency vascular access is rarely required in neonatal resuscitation. If so, umbilical venous catheters (UVCs) are the preferred method due to their ease of insertion and reliable access in critically ill neonates.

Intraosseous (IO) vascular access, often favored by obstetric anesthesiologists familiar with the technique, serves as the second-line option. The proximal tibia is the most commonly used site for IO access in both term and preterm neonates, though its suitability remains debated. Studies indicate that IO access provides faster vascular access compared with UVC placement, with comparable technical error rates [37,38].

PHARMACEUTICAL THERAPY

Epinephrine is the only drug recommended for neonatal resuscitation when the heart rate remains below 60 bpm despite effective ventilation and chest compressions. Intravenous (IV) or IO administration is preferred, while endotracheal (ET) delivery is reserved for cases where IV/IO access is unavailable. Recommended doses are 10–30 μg/kg (IV/IO) and 50–100 μg/kg (ET), repeated every 3–5 min if necessary, though the evidence is weak [24].

Epinephrine use in neonatal resuscitation is rare, with recent data primarily derived from animal studies. A piglet model showed an improved return of spontaneous circulation (ROSC) rate and 6-h survival with epinephrine compared with placebo [39]. Higher epinephrine doses (30 μg/kg vs. 10 μg/kg) enhanced ROSC likelihood and reduced the time to ROSC in a lamb model [40]. Larger saline flush volumes after IV epinephrine administration also improved ROSC rates [40,41].

In neonatal lambs, 100 μg/kg ET epinephrine was ineffective, while 1000 μg/kg achieved ROSC rates comparable to IV administration [42]. IO epinephrine demonstrated similar efficacy to IV administration, with comparable ROSC rates and plasma levels [43]. Direct umbilical vein injection of epinephrine followed by cord milking may be as effective as umbilical venous catheter administration [44]. Intranasal epinephrine showed similar ROSC rates and times to ROSC compared to ET administration but was less effective than IV administration [45]. Data on intramuscular epinephrine remain inconsistent [46,47].

Vasopressin as an alternative to epinephrine showed mixed results. While it was inferior to epinephrine in ROSC rates and time to ROSC in lambs, it demonstrated comparable ROSC rates and longer post-ROSC survival in piglets [48,49▪▪].

POSTRESUSCITATION CARE

Postresuscitative care in neonates should follow Neonatal Resuscitation Program, or the Pediatric Advanced Life Support guidelines prioritizing hemodynamic and ventilator support, glucose, electrolyte, and temperature management, with organ-focused monitoring via electroencephalography, ECG, and echocardiography.

Echocardiography helps to assess cardiac function after, with impaired left ventricular global longitudinal strain linked to increased mortality and poor cardiac function [50].

Hyperthermia (>38 °C) should be avoided, and therapeutic hypothermia is limited to moderate or severe hypoxic-ischemic encephalopathy. Routine use is discouraged and contraindicated in cases such as intracranial hemorrhage, metabolic disorders, or infections [51].

TRAINING AND EDUCATION

Neonatal resuscitation is infrequent in nonspecialized centers, emphasizing the need for structured simulation-based training to improve clinical skills and decision-making (Fig. 1). Digital education tools, including virtual simulations, offer cost-effective and globally accessible training, particularly valuable in resource-limited settings [52,53▪]. Resuscitation skills, which declined by 71% within 6 months, can be maintained using video-based simulations like eSIM (American Academy of Pediatrics, Itasca, Illinois, United States) [54]. Quality improvement tools, such as checklists and debriefing protocols, enhance team coordination and care quality. Technological advances provide additional support. Resuscitation tracking apps improve adherence to protocols, boost provider confidence, and improve documentation accuracy [55]. Telemedical support facilitates postresuscitative care and diagnostics in settings lacking pediatric specialists [56]. Additionally, artificial intelligence offers the potential in predicting clinical deterioration, managing resuscitation, and virtual training via digital twin scenarios, although its application remains confined to research settings [57▪].

CONCLUSION

Advancements in neonatal resuscitation, including DCC, thermoregulation, and airway management, have significantly improved neonatal outcomes and reduced morbidity. Obstetric anesthesiologists play a pivotal role in ensuring timely and evidence-based interventions during emergencies. Ongoing education, adoption of emerging technologies, and integration of artificial intelligence hold promise for further improving care quality. Future research should focus on refining resuscitation protocols for preterm neonates and optimizing training methodologies.

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Conflicts of interest

There are no conflicts of interest.

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- ▪▪ of outstanding interest

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