Delivery Room Intervention: Improving the Outcome

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Video Recording

We initiated a quality improvement program in 1999 and began to video record neonatal resuscitations in our dedicated resuscitation suite and 1 additional obstetric operating room.\textsuperscript{2} Our ongoing quality improvement program involving the video and analog data recording of high-risk deliveries and the subsequent review of such resuscitations,\textsuperscript{3} and our prospective database of all neonatal intubations,\textsuperscript{4} have allowed us to critically evaluate and modify our own practices, and the resuscitation environment.

Videotaping can be an effective training and quality assurance tool and allows the timely recognition of many systematic and procedural errors. Apart from the presence of a dedicated observer, it is the simplest method currently available for objectively measuring outcomes based on monitored data, will allow these types of studies to be performed in the future.

Although more than 400,000 infants in the United States each year require some assistance in the DR, and that intensive resuscitation is required in 1% of all deliveries. A 2001 survey\textsuperscript{1} suggested that 10.6% of infants required bag and mask ventilation at birth.

Although there have been several important single-center studies describing physiologic responses to resuscitation, there are still few prospective randomized trials that evaluate these interventions. Establishing good baseline data through unbiased observation, and measuring outcomes based on monitored data, will allow these types of studies to be performed in the future.
evaluating that the correct intervention was chosen, and that the intervention was correctly applied by individuals and teams during resuscitations. The videotape can be reviewed by many observers, avoiding or reducing individual observer bias, can be replayed for clarification, contains accurate timing information, and the verbal communication during the resuscitation is not subject to recall bias. The audio recording has proven invaluable in assessing communication during resuscitation interventions. The audio information is the basis for determining if there has been appropriate communication, with acknowledgment, and whether team members and leaders interacted constructively. If there were delays in instituting appropriate interventions, the available audio information can confirm that the team was aware of the problem and the reason for any delay. These reviews also provide current information on the capability of the personnel responding, and the need for any further educational efforts. The audio recording provides examples of individuals recognizing potential problems during the resuscitation, and the response to this information.

**Physiologic Data Recordings**

The addition of physiologic measurements to the video recording, including oxygen saturation, pulse rate, \( \text{FiO}_2 \), tidal volume, or end-tidal carbon dioxide, further improves the usefulness of the DR data collection. Our current practice is to gather oxygen saturation, pulse rate, \( \text{FiO}_2 \), airway pressure, end-tidal carbon dioxide and audio on all recordings, with an option to collect an electrocardiogram (EKG) using the BioPac data acquisition and Acqknowledge 4.0 software (Biopac Systems Inc, Goleta, CA). This information is collected any time the wired resuscitation bed is used, whether or not a video recording is obtained. All data are collected at 30 Hz, except for EKG, which is collected at 60 Hz. Analysis includes maximum and minimum values for peak inspiratory pressure (PIP) and positive end-expiratory pressure (PEEP), respiratory and heart rates, and an oxygen saturation histogram. We are now able to evaluate significant detail about the actual interventions, and determine whether they were appropriate and were performed correctly (ie, an increase in \( \text{FiO}_2 \), or an increase in the inspiratory pressure for a bag and mask or intubated breath).

We have frequently found that the medical record documentation of a resuscitation varies considerably from the actual interventions seen on video, including the recording of the number and duration of intubation attempts, the duration of positive pressure breaths, or continuous positive airway pressure (CPAP), and, on occasion, even the failure to mention the use of chest compressions.

Recently, we observed an unintended increase in CPAP/PEEP during a resuscitation (Fig. 1). We believed that this occurred through the inadvertent twisting of the CPAP dial on the T-piece. Without these recordings we would have been unaware of this situation. We immediately provided education to all caretakers to monitor the PEEP/CPAP levels during resuscitation and be aware that such changes were possible, with potentially dire consequences.

There are other parameters that should be more continuously monitored in the minutes following birth and these include the infant’s temperature, measures of tissue oxygenation, and, perhaps, blood pressure. There is a need to evaluate newer techniques to provide such information to the resuscitation teams during this critical period.

**TEAM AND LEADERS**

**The Team**

When evaluating team function, 2 distinct outcomes should be measured. These include evaluating whether the intervention was the correct one, and whether the
intervention was performed correctly. Initial video review of resuscitations at the University of California San Diego Medical Center revealed several problems in the conduct of the resuscitation involving the team, the leader, or both. These problems included more than 1 person doing a single task; other tasks that were not performed at all, such as providing a continuous communication of the infant’s heart rate; the lack of the provision of blow-by oxygen or cricoid pressure during intubation; and poorly coordinated or completely uncoordinated compressions and ventilation.

The ideal qualities and functions for the team and its leader were developed using the observations of Cooper and Wakelam.6 These qualities and functions included adequate preparation, having resuscitation team members who were adaptable, and who coordinated their activities and interventions using acknowledged clear and concise communication, under the direction of a calm and knowledgeable leader.3 Clear and acknowledged communication is the most basic vital function of a good team, and is the 1 function that fails most frequently. Crew resource management (CRM) is a methodology developed for the training of aircrews during the late 1970s that evolved from a careful evaluation of the role of human error in air crashes.7 CRM is the basis for much of the team and leader training used in various medical areas, including the operating room, the emergency room, and the DR in our institution. Robert Helmreich, 1 of the original designers of the process, describes the fifth generation of CRM, established in 1997, as an error management tool with 3 fundamental countermeasures.8 These countermeasures are avoidance, trapping, and mitigation. The use of CRM fundamentals in the DR environment to manage errors and improve outcomes can and should include all of these measures.

Avoiding errors requires some system of pre-event communication, based on an established procedure. Knowing what each team member is supposed to do while in the DR, and providing consistent training to ensure that they know how to perform each of those tasks, eliminates errors such as multiple individuals performing 1 task,
and almost by definition, omits others. A prebrief ensures that roles are understood, that the specifics of a given delivery are provided for, and that each member is reminded that they are expected to speak up if they see something that concerns them. Planning and performing a prebrief for all resuscitations goes a long way toward avoidance of errors.

Trapping errors is accomplished in the cockpit by cross-checking, the process of checking information using a second source. For instance, in the DR, an oximeter registering a heart rate that is slow in an infant who seems otherwise stable can be cross-checked with a stethoscope.

Mitigation occurs when an error, already defined as an inevitable part of human interaction, is minimized by recognizing it quickly. The use of all the tools that are available, although not depending on a single number to determine patient status, decreases errors and improves outcomes. Every team member sees the process from a different perspective, and their information should be acknowledged and processed. Empowering each team member to verbalize any concern during a resuscitation increases the likelihood that such an error is recognized and avoided.

This process of reviewing, monitoring, and predicting is referred to as situational awareness, 1 of the primary functions of the team leader.

The Leader

The primary role of the leader is to bring together the first 2 processes discussed earlier, making sure that the correct interventions are chosen and that they are performed correctly. To accomplish these goals, the leader must have what is referred to in CRM as situational awareness, the single most important function of the leader during a DR resuscitation.

If the team has chosen the wrong intervention, or someone is not skilled in a particular task, or they are too busy to carry out a particular intervention, it is up to the leader to recognize this while still maintaining an awareness of the status of the infant. This effort requires a skill called scanning, whereby the leader goes through a mental checklist of critical processes. This list includes checking environmental factors such as bed temperature, technical problems such as not properly assessing heart rate, and communication issues such as not repeating back orders, all while assessing the status of the infant, predicting the future course, and determining the appropriate next step. (We have found that some are uncomfortable with the term orders, as it denotes a military type of rule, but it is simply the best term for a call for a specific action at a specific time.) Scanning should take place every minute to ensure that no errors of omission or commission go unnoticed for a significant period of time.

Communication is the primary framework of CRM and of resuscitation leadership also. A good leader has the ability to provide commands clearly and succinctly, while encouraging and integrating the suggestions of other team members. Our scoring looks for orders that are relayed to a specific person, not the group (“Mary, get me some Epi”, not “Get me some Epi”), and that are acknowledged.

Errors that lead to less than optimal outcomes can also occur if everyone at the resuscitation does not believe that they are empowered to stop them. A prebrief should include a specific statement, to be read every time, that encourages everyone that if they see something they are not comfortable with, they should communicate it to the leader. A good team and leader will ensure that once the appropriate interventions are established, they are performed in such a way as to truly decrease errors and improve outcomes.

In a trial incorporated into the advanced life support provider course in the United Kingdom, Cooper and Wakelam showed that a formal leadership program
significantly improved leadership performance in the simulated environment of a training scenario. We have taken our previously validated resuscitation scoring tool\textsuperscript{9} and added a component to measure leadership skills based on CRM fundamentals. Video review combined with specifically defined errors and acceptable deviations has been shown by Oakley and colleagues\textsuperscript{10} to be better than chart review in recognizing management and leadership errors, although less effective in recognizing items like dosing errors that are not easily visualized. This group also noted that the absolute number of management errors was high in their trial because of the nature of video review and its superiority to clinician memory. The most effective way to use a scoring tool during resuscitation is to combine it with a video review.

The leadership skills incorporated into our tool include prebriefing, maintaining situational awareness, reinforcing good communication, empowering team members, and conducting a debrief. The prebrief is simply scored as having occurred or not having occurred. The checklist forces each team member to be prepared and review their own functions during the upcoming resuscitation, and provides a time for questions. For example, a team that has discussed the need for a bag to protect an infant with a gastroschisis is more likely to have one available and use it.

The postbrief is meant to allow for a review, and it is purposefully kept simple, asking 3 questions: “What did we do well?”; “What could we do better?”; and “How could we do it better?”

During the video review, there is another opportunity for a postbrief, and the benefit of this review is that many more individuals can participate and learn from a single team’s experience.

**Resuscitation Environment**

An infant who receives care in a neonatal intensive care unit (NICU) is placed in an environment that provides servo-controlled temperature regulation, continuously monitored vital signs, and oxygen saturation. Supplemental oxygen is provided with a heated, humidified, blended gas source, and positive pressure ventilation is provided by sophisticated devices that provide for consistent, well-monitored ventilation. Historically, however, during the first few critical moments of the same infant’s life, the infant may be cared for in a part of a room designed for the delivery and the mother, with less attention to the needs of the resuscitation team and the infant. The heart rate might be determined by palpation or auscultation, and oxygenation was often assessed from the infant’s color, a method that has been shown to be ineffective.\textsuperscript{11} The bed was most likely an NICU castoff. Ventilation, if required, was provided using a manual device without heat or humidification, which may or may not have adequately controlled the level of PEEP. These differences in environment and management in the crucial first minutes of life seem paradoxical and irrational, and are not based on any controlled outcome data. In addition, in our experience infants with extremely low birth weight (ELBW) stay in the DR following delivery for \(22.5 \pm 9\) minutes, consistent with earlier observations.\textsuperscript{12,13} As pointed out by Vento and colleagues\textsuperscript{14} high-risk deliveries should be performed in perinatal centers with adequate staffing, in an environmentally appropriate room specifically designed to evaluate and treat newborn infants.

**Temperature Support**

The accepted standard for preterm infants and nonasphyxiated term infants is an environment that provides for minimal heat loss and optimal metabolic oxygen consumption. These requirements are especially important for infants with ELBW because of their increased surface area to body weight ratio, their immature skin without
a well-defined stratum corneum or covering vernix, their lack of subcutaneous tissue, and their poor vasomotor control, all of which can lead to hypothermia following delivery. The International Standard for Infant Warmers (IEC 60601-2-21) requires that a radiant warmer should cut power and sound an alarm if the total output has been higher than 10 mW/cm$^2$ for more than 15 minutes. As all current warmers are greater than this on 100% power, during prolonged and difficult resuscitations they will reduce heat output to meet this standard. We strongly suggest that servo probes are an essential part of the resuscitation process and can decrease hypothermia and hyperthermia, both of which can be harmful to the neonate. A team member must monitor the heat output if a servo probe is not applied to ensure that the sickest and smallest infants who spend the most time in the DR are protected from hypothermia and hyperthermia.

The use of some type of occlusive wrap has become standard in infants of less than 28 weeks’ gestation. The EPICure study found that 36% of infants of 24 and 25 weeks’ gestation had NICU admission temperatures less than 35°C. Vohra and colleagues showed that a polyethylene occlusive wrap in preterm infants is associated with a significant increase in mean admission temperature (1.9°C, $P < .001$) and survival ($P = .04$). The improvement in admission temperature has been a consistent finding in multiple studies. Other methods of maintaining temperature (mattress pads and Kangaroo care) also have a positive effect on admission temperature, with skin-to-skin also providing improved bonding between mother and child. The use of hats to maintain temperature has mixed results depending on the material used.

It is probably most sensible to use some combination of these practices in conjunction with skin-temperature probes and servo control of radiant-warmer output to avoid hyperthermia and a drop in the heater output when in full-power manual mode for more than 15 minutes. An increase in the DR temperature also facilitates the maintenance of adequate core temperatures in the infant with ELBW. Admission temperatures that are in the hypothermic range have been associated with increased risk for mortality and late-onset sepsis. Therefore, every effort should be made to keep the preterm infant’s temperature within normal limits during resuscitation and transport.

The routine use of servo-controlled infant temperature probes, plastic wrap, and chemical warmers for infants with ELBW, maintenance of an adequate room temperature (we use 85°F), and frequent monitoring of the infant’s temperature by the team (every 5 minutes) decrease the incidence of hypothermic and hyperthermic NICU admissions.

**Pulse Oximetry**

The use of pulse oximetry has been included as a tool in the current textbook of the neonatal resuscitation program, but there is no evidence-based recommendation regarding its use. We instituted the use of pulse oximeters (POs) during resuscitation to provide continuous heart rate and a quantitative determination of oxygenation, 2 of our previously established requirements for a well-controlled resuscitation. In reviewing resuscitations, we found that the current recommendation of intermittent heart rate checks using a stethoscope or cord palpation was inadequate for infants receiving advanced resuscitation and that having a team member assigned to indicate continuous heart rate visually was more helpful in assessing the benefit of any intervention. Oximeters can effectively fulfill this function, although a useful signal is rarely available within 1 minute of birth. Our current observations seem consistent with those of Lundstrom, who placed a PO on the right hand of 12 infants in each of their groups of premature infants and noted that useful information was obtained at approximately 3
minutes of age. The use of shorter averaging intervals, maximal sensitivity, and POs with excellent motion artifact rejection should decrease the interval between application and function of the PO in the DR. Continuous palpation/auscultation of heart rate during resuscitation is vital to gauge the effects of resuscitation interventions, and should continue until the PO is operational.

Knowledge of the normative saturation values for infants at the time of delivery is improving. A composite of the increase in \( \text{SpO}_2 \) in infants following birth is shown in Fig. 2, with the red dot approximating the expected fetal \( \text{SpO}_2 \) of approximately 45% to 55% and therefore the \( \text{SpO}_2 \) immediately after a birth without complications. Targeting an \( \text{SpO}_2 \) of 70% at 4 minutes and 80% at 7 minutes represents an absolute increase of 5% per minute, and is consistent with previous observations of the increases in \( \text{SpO}_2 \) following delivery in the preterm nonresuscitated infant.

With minimal experience, it is possible to monitor oxygen saturation in the first few minutes of life. Management by color is inaccurate and inconsistent and is significantly affected by ambient light. Although it is often not functional within the first minute, the early use of the PO in the DR should be the standard for any infant requiring resuscitation.

**Supplemental Oxygen**

The correct delivery of oxygen requires tools that have become the standard in the NICU environment, but less so in the DR. To use a targeted oxygen strategy, a functioning oximeter as described earlier needs to be available as soon as possible after delivery, with compressed air and an oxygen blender.

There is currently no agreement about the initial or optimal oxygen concentration for resuscitating the infant with ELBW. The current neonatal resuscitation program guidelines indicate that such resuscitation or stabilization may be performed with any oxygen concentration and that a PO should be applied and blenders must be available to facilitate the optimal \( \text{SpO}_2 \) values during resuscitation. Accumulating evidence in term infants suggests that the initial use of 21% versus 100% oxygen for resuscitation is associated with a significant lowering of mortality.

The optimal oxygen saturation values and associated \( \text{FiO}_2 \) levels for the resuscitation, stabilization, and ongoing care of very preterm infants remain undefined. There have now been multiple small prospective randomized trials comparing the use of lower and higher oxygen concentrations during neonatal resuscitation in preterm infants using some range of targeted \( \text{SpO}_2 \). The outcomes evaluated were...
short-term effects of differing oxygen concentrations on SpO₂ changes immediately after birth. Vento and colleagues reported a decrease in biparietal diameter (BPD) in their low inspired oxygen group, a benefit which has not been reproduced in the other trials. The oxygen level that yields the best long-term outcome in the preterm population has not as yet been determined in a multicenter randomized controlled trial. We use and recommend an initial \( \text{FiO}_2 \) of between 0.30 and 0.40 for such infants and then attempt to achieve an increase of SpO₂ of approximately 5% per minute to a target of 85% to 90\%.

**Airway Maintenance**

Approximately 85% to 90% of the most immature infants require assisted ventilation as part of their neonatal care. The standard approaches to provision of this support include bag and mask ventilation, followed if necessary by endotracheal intubation. A patent airway is critical during each of these maneuvers. Chest wall movement is the most common method of determining adequacy of ventilation with bag and mask. The visualization of chest rise is often difficult because of operator position, a crowded bed space, infant size, and the use of plastic wrap. The ability to recognize adequate chest rise in the infant with ELBW, a subtle finding that may be confused with abdominal rise, is difficult and requires clinician experience. Tracy and colleagues have shown that hypocarbia and hyperoxia occur frequently in the intubated, ventilated preterm infant during resuscitation when chest rise is used as a marker for determining appropriate ventilatory pressures.

We have introduced the use of a colorimetric, semiquantitative, carbon dioxide detector to assist in the recognition of airway patency during bag and mask ventilation. We found that more than 80% of infants with ELBW receiving bag and mask breaths have evidence of airway obstruction during the initial breaths that may persist for more than 37 breaths and more than 1 minute. These obstructed breaths may often go unrecognized in the absence of a CO₂ detection device and can lead to hypoxia and bradycardia, requiring further, more aggressive, hazardous procedures, such as increased inflating pressures, compressions, or medications, if they are not rapidly recognized and relieved. Such airway obstruction may present an urgent indication for intubation if it cannot be resolved by other means.

The authors and others have shown that the placement of an endotracheal tube (ETT) in a newborn infant is associated with significant adverse physiologic effects, including bradycardia, fluctuations in blood pressure, hypoxia, and increases in intracranial pressure. The most common indications for intubation in the infant with ELBW are (1) absent or inadequate respirations; (2) ineffective or prolonged bag and mask ventilation; and (3) surfactant administration. Because the ETT provides a direct path to the trachea, it is generally assumed that once an infant with no meconium is intubated, the need to monitor for a patent airway is diminished. Our review of video and recorded physiologic parameters in infants who are receiving surfactant, using either a direct-installation method or a purpose-built in-line adaptor, suggests that surfactant is often responsible for partial obstruction of the ETT. As seen in the recording in **Fig. 3**, end-tidal carbon dioxide levels do not return to baseline after administration of surfactant, suggesting a longer transit time of ventilatory gas through a smaller orifice, compatible with a partial airway obstruction.

From our video reviews we showed that the overall success rate for neonatal intubation during resuscitation was approximately 33% within the allotted 20 seconds stated in current guidelines, and 56% successful overall using a 30-second duration. The authors and others have subsequently reported that the failure rate using a 30-second interval is substantially greater for infants of less than 28 weeks’ gestation.
A detailed review of the last 5 years of this database has demonstrated that on average, at least 3 attempts are required for the successful intubation of infants of less than 1000 g birth weight.

Training

Our current practice is to provide individualized resuscitation training for all residents rotating through the NICU. An analysis of this process by Garey and colleagues has shown that repeated training improved resuscitation skills. There does not, however, seem to be a clear relationship between manikin practice and successful clinical intubation skills. Our practice is also to provide feedback by way of video review for all intubations that occur during resuscitation. Although review of video provides significant detail regarding an operator’s approach and skill, and increases understanding of what needs to occur, the acquisition of such a skill requires significant real world experience. There is no substitute for experience in learning the skill of endotracheal intubation, and adequate resources need to be provided for pediatric residents to allow for mastery of this vital skill.

Current instrumentation is not designed specifically for infants with ELBW and requires manipulation of the infant to achieve adequate visualization of the larynx. The currently available laryngoscope blades, including the Miller 00, do not allow adequate visualization without excessive and often forceful cricoid pressure and change in head position (Fig. 4). The size and shape of current blades leave little space in the upper airway in which to insert and pass an appropriately sized ETT through the larynx while maintaining an adequate view of the larynx.

Even with conventional instrumentation, the process of intubation can be improved. The shortest distance that an individual can bring into focus without visual correction...
increases with age and is approximately 14 cm at 30 years of age, 22 cm at 40 years, and at least 40 cm by 50 years of age. The smallest available laryngoscope blades, Miller 00, are approximately 6 cm in length and most operators place their eye close to the proximal end of the blade. We have placed magnifying glasses and loupes in our DRs to facilitate clarity and perceived size of the larynx. Failure to visualize the laryngeal inlet adequately almost always results in the tube passing into the much larger and posterior esophagus. Improved tools for intubation of the infant with ELBW will help ensure intubation is accomplished successfully.

**T-Piece Resuscitator**

The T-piece, a simple pressure-limited manual ventilation device, has gained favor in neonatal resuscitation. We previously studied the ability of our staff (including nurses, respiratory care practitioners, and physicians, including residents, fellows, and neonatologists, and neonatal nurse practitioners) to provide bag and mask ventilation using an anesthesia bag and the Neopuff (Fisher & Paykel, Laguna Hills, CA, USA). The participants were asked to use a specific pressure and rate algorithm. The PIP and PEEP were significantly different between operators using the 2 manual bagging devices, but all operators could generate the target PEEP with the Neopuff ($P<.001$). The PIP was similar for all groups using the Neopuff device.

We also observed that more than 61% of breaths delivered by an anesthesia device failed to stay more than 3 cm of PEEP, whereas 31% failed to reach the prescribed PIP. Oddie and colleagues reported similar results in a preliminary publication comparing 3 devices, 1 of which was a T-piece. They noted that for 15 of 25 studies the operators using a 240-mL bag exceeded the peak target pressure, and that prolonged inflations could be delivered with a T-piece. The use of a device that provides consistent target pressures regardless of the skill level of the operator has the potential to decrease barotrauma and improve pulmonary outcomes. Insuring that the intervention is performed properly requires operator awareness of potential drawbacks like difficulty in increasing pressures and the administration of inadvertently increased CPAP levels.

**Outcome Measures**

This article focuses on interventions that can improve the outcome of infants resuscitated in the DR. Gestational age and birth weight at delivery are the most
important predictors of survival in extremely premature infants. Many additional modifying factors have now been recognized, however, that contribute to the risk of mortality and morbidity for this population, including race, gender, multiple gestation, antenatal steroids, Apgar scores, institutional experience, and illness severity scores.53,54

Several outcome measures can be collected early, for example admission blood gases, ideal PaCO2, admission temperature, and the need for intubation or surfactant. To power prospective studies using these measures, it is necessary to determine the current baseline data for different populations in the DR. We have reviewed the DR interventions and admission status of 193 infants with ELBW in a single institution between 2001 and 2006.13 Male sex, prolonged premature rupture of membranes, lack of exposure to prenatal steroids, and an initial blood gas with low pH or high lactate levels were found to be significant independent predictors of early death and severe intraventricular hemorrhage. Mean admission values for temperature, oxygen saturation, and PCO2 on the first blood gas were 36.4°C, 95%, and 66.8 torr, respectively. Larger trials relating DR interventions to short-term outcomes are necessary.

Establishing which DR interventions result in the best outcomes requires planning, teamwork, leadership, and continued analysis by large multicenter randomized trials with adequate power to mitigate the many variables that stand between the initial intervention and the final outcome.

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