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Anticipation and preparation for delivery room emergencies

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ABSTRACT

Effective communication is the keystone in the management of delivery room emergencies. A clearly defined framework and "shared mental model" optimize team collaboration and are essential when anticipating and preparing for high-stakes emergent cases. This review defines a framework to build shared mental models using dialogue, pre-briefing, checklists, simulation, debriefing and structured feedback to maintain a cohesive high functioning team. Strategies to approach different emergency lead-times will be discussed, and case examples will be used to illustrate concepts outlined.

1. Introduction

Delivery room (DR) emergencies are among the highest stakes clinical scenarios a provider may face related to the care of the newborn. Often fraught with wide variability, these emergencies may be anticipated, as a result of a known fetal anomaly within an identified "high-risk pregnancy," or may only become apparent during labor or resuscitation. Neonatal resuscitation teams should be trained in management of these expected and unexpected DR emergencies.

Anticipation and preparation are central to mitigating uncertainty. In many cases, teams can anticipate risk factors for increased likelihood of more interventions in the DR [1]. The foundation of anticipation and preparation for DR emergencies is built on identifying and gathering optimal information, personnel, and equipment for the resuscitation, while maintaining a shared mental model through effective communication. A recent review by Sawyer et al. outlined methods of anticipation and preparation for every DR resuscitation [2].

The purpose of this report is to build upon those concepts, focusing on how teams can create a shared mental model during DR emergency resuscitation through preparation, debriefing, review, and simulation. Specific medical management of each emergency is beyond the scope of this review.

The discussion will be organized by the time allowed for preparation prior to delivery (see Fig. 1), covering preparation of:

1. Unanticipated emergencies with minimal time to prepare
2. Unanticipated emergencies with no time to prepare
3. Anticipated potential DR emergencies with time to prepare

To consolidate concepts, an institutional example of an antenatally identified case of cloacal malformation complicated by hydrometrocolpos and development of a large intraabdominal collection with resultant pulmonary hypoplasia will illustrate an anticipated potential DR emergency and how multi-disciplinary preparation affected DR management.

2. Shared mental models

The key to successful team management of DR emergencies is effective communication and teamwork [3,4]. Teams can communicate and function more effectively when they have a shared mental model [5,6]. This is defined as "the perception of, understanding of, or knowledge about a situation or process that is shared among team members through communication" and has many benefits for team dynamics.

"Shared mental models can help teams by [7]:

- Leading to mutual understanding of situations
- Leading to more effective communication
- Enabling team members to back up and fill in for each other
- Enable better prediction and anticipation of team needs
- Create commonality of effort and purpose"

In neonatal resuscitation, critical time points for establishing and re-establishing shared mental models are:

- Prior to delivery (with a pre-brief)
- During resuscitation or emergencies (with recaps)
- When reviewing the resuscitation as part of the transition to post-DR care (during the debrief)

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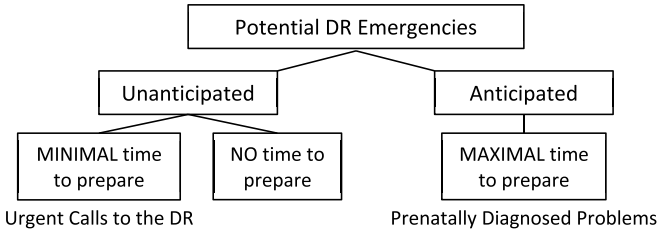

Fig. 1. Anticipation and preparation for delivery room (DR) emergencies.

Table 1
Anticipating and preparing for delivery room emergencies.

For EVERY Individual Delivery	Developing and Maintaining Expertise Globally
Communication with OB	Regular resuscitation review
Communication with the family	Simulation
Equipment/personnel checklists	
Pre-briefing	
Debriefing	

Maintaining a shared mental model from the preparation period before through the stabilization period after resuscitation keeps teams cohesive and helps them respond more expediently to any emergencies that may arise [8].

Table 1 illustrates how shared mental models are established for individual deliveries and how the skills related to them may be practiced and improved on a broader scope. Each element will be discussed in detail.

3. Anticipation and preparation prior to every delivery

3.1. Communication with the obstetric team prior to delivery

Communication with the obstetric team should begin as early as possible. Scheduled times to jointly "run the labor board" may be helpful to provide an overview of imminent deliveries and keep neonatal teams updated on higher-risk deliveries and anticipated admissions to the neonatal intensive care unit (NICU). Prior to each delivery, the "four pre-birth questions" should be ascertained as recommended by the Neonatal Resuscitation Program (NRP). These include gestational age, number of babies, presence of meconium and presence of any additional risk factors [9]. Additional information, such as the review of the fetal heart rate tracing and estimated fetal weight, particularly in the case of preterm infants, may be helpful for framing expectations, choosing equipment (appropriately sized laryngoscope or endotracheal tube) and calculating medication doses prior to delivery.

When called for deliveries, transmission of this information to the responding neonatal provider/team in real time is ideal. This allows early anticipation and preparation, an opportunity for clarification of information and confirms that a neonatal provider/team are aware and will be in attendance of the delivery. Importantly, this also allows for more effective triage of personnel and reallocation of resources, as neonatal providers/resuscitation teams are often pulled from other duties in the newborn nursery or NICU.

3.2. Communication with the family prior to delivery

When possible, introduction of the neonatal team to the family should occur prior to delivery. In high-risk pregnancies, antenatal counseling for sharing information and ascertaining a family's values and preferences is critical to framing neonatal management, particularly when outcomes are uncertain. This should be performed jointly with the obstetrics team prior to delivery when possible [10]. Discussion related to best practice of antenatal counseling is outside the scope of this review.

Table 2
Information to provide families in the delivery room when emergencies are anticipated.

General Preparation	Where will resuscitation occur (if not in the same room as delivery)?
	What might resuscitation include?
	When can they expect an update?
	When will they be able to see the baby?
Specific Preparation	What can they expect the baby to look like?
	What is a potential timeline for transfer to the NICU?
	What studies/interventions may occur after birth?
	Who will evaluate the baby in the NICU (teams/specific providers)?
	When should the parents expect to be able to speak to someone?

If DR emergencies are anticipated, discussion of where resuscitation occurs (if not in same room as delivery), potential interventions, and providing an estimate of when they will be able to see their baby can be helpful to prepare family expectations and should be prioritized where possible. More detailed preparation and review of postnatal care and expectations should occur when admission to the neonatal intensive care unit (NICU) is anticipated. Table 2 outlines points to consider discussing with families when DR emergencies are anticipated.

3.3. Personnel

Members of the neonatal resuscitation team should be trained in DR management of the newborn and competent in identifying and addressing problems and emergencies if they arise. Inclusion of specific advanced providers or additional personnel can be considered depending on the circumstances and degree of concern identified [11]. If not initially present, methods of reaching these providers, should also be clearly stated. Team members with specific knowledge of the resuscitation area, including where to obtain additional supplies and equipment may be an invaluable resource. Roles of all team members should be clearly delineated prior to delivery, particularly the identification of a team leader [9,12].

3.4. Equipment

Availability of all equipment for neonatal resuscitation is essential for successful resuscitations. This is increasingly true when emergencies arise in the DR. Checklists, such as the NRP "Quick Equipment Checklist" are useful in ensuring all equipment is visually identified and checked prior to delivery [11]. Delegating responsibility so that team members are responsible for checking the equipment necessary in their specific role may streamline the process, particularly when time is limited.

When risk factors identify the need for specific equipment, this should be intentionally stated, especially if that equipment is less commonly used in the DR. These may include equipment for thermoregulation (thermal mattress, plastic bag/wrap) when preparing for the delivery of a preterm infant, or a meconium aspirator when meconium stained amniotic fluid is present.

3.5. The pre-delivery briefing, or "pre-brief"

Pre-briefing is an important method of preparing teams and should be performed prior to EVERY delivery. It allows the team to establish a shared mental model specific to the case, anticipate and prepare for what may occur, and provides an opportunity for team members to raise questions and clarify plans and has been shown to improve teamwork and communication [13].

The pre-brief should include a discussion of the specific risk factors identified, potential interventions the newborn may require, and importantly when and how these interventions integrate into the NRP

Table 3
Elements of the pre-brief.

Review of specific risk factors identified and problems that may result
Discussion of potential interventions that may be required
When these interventions will occur in resuscitation/How they integrate into the NRP algorithm
Assignment of roles/responsibilities
Who/how to call for additional support if needed
Equipment Check
Review of teamwork principles

algorithm, as well as roles assigned to each member of the team (see Table 3). Contingency plans should be discussed, which may include methods of escalation if additional personnel or equipment are required. A brief reminder of optimal teamwork principles, such as speaking up if concerns are identified, use of closed loop communication, and cross-monitoring, should also be provided [14].

Thorough team pre-briefs are especially critical in large institutions with providers of varying training and experience, and where members of the neonatal resuscitation team are often changing, with new combinations of team members being formed each shift [15]. Establishing this shared mental model and identifying contingency plans result in more organized resuscitations, quicker time to life-saving interventions and improved team functioning [16].

3.6. Debriefing

Debriefing is a "facilitated or guided reflection in the cycle of experiential learning" [17].

It serves as a valuable team-reflection exercise to determine the efficacy and accuracy of the anticipation/preparation prior to delivery, assess communication and team dynamics, and review medical decisions made during the resuscitation. Regular group- and self-reflection, leads to changes in ways we conceptualize information and serves as the next step in the cycle of learning [18]. This reflective process helps individuals and teams continuously improve their abilities to anticipate, prepare and communicate in emergency scenarios and informs future performance.

Debriefing should occur after every delivery, and especially after critical events. It may be brief and take the form of "plus-delta," where teams review things that went well and things that could be improved upon [19]. Debriefing tools or scripts are helpful in guiding facilitators and teams through the process and serve as a platform for starting these discussions [2,20].

4. Developing and maintaining expertise in management of DR emergencies

Beyond individual deliveries, anticipation and preparation for DR emergencies should occur on an institutional level. This may occur through regular review of resuscitations to identify areas for ongoing improvement, or development and maintenance of expertise through simulation.

4.1. Review of resuscitations

Regular review of collected debriefings from individual resuscitations, particularly where DR emergencies were present, provides neonatal resuscitation programs a forum to ensure ongoing quality improvement on a broader scale [21,22]. Multi-disciplinary representation is optimal for productive discussions in this forum and may include neonatal and obstetric physicians, nurse practitioners, nurses, trainees (fellows/residents), respiratory therapists, educators and potentially others.

Through the lens of these diverse perspectives, problems identified in debriefings, such as those related to equipment, systems or processes, may be further defined and addressed and joint solutions arrived at more quickly. Broad knowledge gaps may be identified and methods of integrating these topics into educational curriculum discussed. Review of details of individual cases may also aid in large-group reflection on practice [8].

This forum also serves as a point of communication between two closely tied clinical services. Regular discussion keeps all team members abreast of changes in staff, equipment, policy, procedures, etc. on either unit, while providing an opportunity for feedback.

4.2. Use of simulation to develop expertise in the management of DR emergencies

4.2.1. General preparation

Resuscitation reviews can be coordinated with simulation programs to further characterize problems, streamline processes and build clinical expertise in scenarios of DR emergencies. These emergencies may arise in various forms (a "difficult airway", hypovolemia, etc.), in various areas and with varying amounts of warning. Simulation provides a low-stakes setting to practice and prepare for all of these high-stakes scenarios.

When designing these multi-disciplinary simulations, learning objectives will center around the rapid identification and management of clinical emergencies. In addition to focusing on knowledge and clinical skills, training sessions should also include review of hospital policies and procedures. As examples, in the case of the "difficult airway," escalation protocols and methods of contacting sub-specialty support during an active resuscitation should be regularly reviewed and tested. In the case of profound hypovolemia, training may include review of procedures to emergently access and deliver un-crossmatched, O-negative blood.

Difficulty of scenarios may be titrated commensurate with the experience of the team. For example, for more experienced teams, limited information may be provided in order to challenge team members to ask specific information that will be helpful for the resuscitation, and the time allowed for anticipation and preparation prior to "delivery" may be decreased. Conversely, difficulty may be titrated downwards for less experienced teams by providing more information and time prior to the start of the scenario. When debriefing these scenarios, specific focus should be placed on how anticipation and team preparation prior to delivery facilitated resuscitation, and how to perform these critical steps more expeditiously.

Simulation scenarios may also be written to mirror upcoming high-risk deliveries (such as the scheduled delivery of an infant with a neural tube defect). This offers teams a "dress rehearsal" and additional opportunity of anticipating and preparing for situations that may arise in the delivery room.

In situ simulations in all clinical areas that emergency resuscitations may occur will also benefit team preparation [23]. Performing simulations in active clinical areas (e.g. operating rooms or DRs) offers increased realism, providing an opportunity for team members to familiarize themselves with the setting and particular challenges of the space [24]. In situ simulations may also identify problems related to staffing, communication and equipment, and provide a method of testing potential solutions, without bringing harm to a patient [23]. This may be especially helpful in settings where neonatal resuscitation occurs infrequently and delays to getting appropriate equipment or lack of familiarity with the clinical area may lead to delays in appropriate intervention, resulting in progression from a less severe problem to an emergency. These settings may include the emergency room, triage area of the labor and delivery unit and the antepartum area. Information uncovered during these simulations should be disseminated and reviewed with members of the resuscitation team.

4.2.2. Use of simulation to prepare for specific, anticipated DR emergencies

In addition to the preparation for general DR emergencies, simulation may also be utilized in high-risk deliveries, where fetal anomalies

have been identified and specific DR emergencies may be anticipated. In these scenarios, simulation can be employed to develop, test and optimize resuscitation plans and serve as a "dress rehearsal" for practice.

Patient specific models or manikins can be built to provide team members with a realistic replica of the anomalies and challenges they may face in the DR [25,26]. Using this model, the multi-disciplinary and sub-specialty teams involved in the delivery can trial different approaches and strategies to resuscitation and identify an optimal method. After the plan is established, the team can practice the orchestration of a complex resuscitation as well as anticipated emergencies that may arise [27].

Given the large numbers of people at times required at these deliveries, in-situ simulation may also help to further refine the resuscitation plan. Simulation in the actual DR setting will provide a more accurate sense of space allotted to each person, lighting, noise and identify other ergonomic issues [24]. These in turn will inform ideal placement of personnel and equipment. This may be especially useful for those who are unfamiliar with the DR and its typical set up.

5. Potential emergencies arising just prior to delivery – MINUTES to anticipate and prepare

Emergencies arising just prior to delivery often result in urgent calls to the DR, where time for team preparation is limited (see Fig. 1). Examples of these may include preterm birth (< 28 weeks), maternal trauma, umbilical cord prolapse, significant fetal heart rate abnormalities and presence of thick meconium. These cases represent high-risk deliveries with an increased likelihood that the newborn will not respond to the initial steps and bag mask ventilation [1]. Teams should anticipate that these newborns may require advanced maneuvers such as placement of an advanced airway, chest compressions, medications or additional interventions not usually employed in routine resuscitation.

For each risk factor identified, resuscitation teams should anticipate related problems or emergencies that may occur, along with potential interventions. All of these should be clearly discussed in the pre-brief so that the neonatal team forms a shared mental model of the anticipated resuscitation. Table 4 provides examples of risk factors and their potential problems and related interventions.

As an example, in the case of a preterm infant (< 28 weeks), specific DR challenges relate to lung immaturity and respiratory distress syndrome (RDS), difficulty establishing a functional residual capacity (FRC) and high risk of heat loss. To address the first risk factor of lung immaturity, potential interventions may include immediate use of positive end expiratory pressure (PEEP) for lung recruitment and alveolar stabilization, starting at a higher fraction of inspired oxygen (FiO_2) (30% vs 21%), and need to escalate to higher peak inspiratory pressures (PIP) initially. For the risk of heat loss, use of a thermal mattress and plastic bag/wrap immediately after birth, with placement of a temperature probe to ensure thermoregulation may be performed. Additionally, given that preterm infants may decompensate very quickly when poorly ventilated, early placement of an electrocardiogram (ECG) can direct resuscitation and provide expedient feedback on effectiveness of interventions. And given the preterm infant's vulnerability to oxygen exposure, early placement of a pulse oximeter will aid in targeting oxygen delivery. Promptly addressing ventilation in the context of presumed RDS and risk of heat loss during the resuscitation of this preterm newborn will hopefully prevent emergencies from arising (such as prolonged poor ventilation leading to the need for chest compressions) [28].

6. Unexpected emergencies arising at/after birth – NO TIME to anticipate and prepare

Unanticipated emergencies may arise during the birth process or resuscitation itself, requiring teams to identify and address problems in real time (see Fig. 1). These should be considered if the depressed neonate fails to respond as expected to routine resuscitation and provision of effective ventilation. Examples may include potential exposure to intrapartum hypoxia-ischemia, hypovolemia secondary to an acute fetomaternal hemorrhage, undiagnosed airway malformation or pneumothorax (see Table 5).

Effective team management during an emergency should focus on clear communication and use of "recaps" as necessary to establish/re-establish a shared mental model [29]. In situations where an unanticipated emergency arises, it is not uncommon for team members to break off into silos to gather more information and troubleshoot reasons for failure of the newborn to respond to expected interventions. This often results in increasing noise and lack of consensus, leading to loss of critical information and increasing stress among the team and onlookers (which may include parents).

6.1. Use of recaps

The use of "recaps" is helpful to quiet the room and re-organize the team. Stated by a single person, often the team leader [29], recaps include a brief description of what is known and unknown, current

Table 4
Examples of anticipating potential problems and interventions based on risk factors identified prior to delivery.

Risk Factors	Potential problems	Potential Interventions
Preterm birth (< 28 weeks)	RDS	Use of PEEP, may require higher PIP to start
	Difficulty establishing FRC	Consider starting at 30% FiO_2
	Risk of heat loss	Early placement of monitoring devices
		Use of thermal mattress and plastic bag/wrap
Placental abruption	Potential for hypoxia-ischemia	Intubation, UVC, chest compressions ± epinephrine
	Respiratory depression	
Maternal trauma	Hypovolemia	Volume (O-neg blood or normal saline)
	Hypoxia-Ischemia	UVC, chest compressions ± epinephrine
	Birth injuries	Careful handling and complete survey
Umbilical cord prolapse	Potential for hypoxia-ischemia	UVC, chest compressions ± epinephrine
	Hypovolemia	Volume (normal saline)
Potential shoulder dystocia	Birth injuries	Careful handling and complete survey
Significant fetal heart rate abnormalities	Potential for hypoxia-ischemia	Intubation, UVC, chest compressions ± epinephrine
	Respiratory Depression	
Presence of thick meconium	Tracheal obstruction	Use of meconium aspirator for airway clearance
	MAS	Needle thoracentesis if pneumothorax present
		Use of higher PIP

RDS: respiratory distress syndrome, FRC: functional residual capacity, PEEP: positive end expiratory pressure, PIP: peak inspiratory pressure, FiO_2: fraction of inspired oxygen, UVC: umbilical venous catheter, MAS: meconium aspiration syndrome.

Table 5
Unexpected emergencies arising in the delivery room.

Perinatal depression secondary to hypoxia ischemia
Hypovolemia
Difficult airway
Undiagnosed airway malformation
Pneumothorax
Emergencies related to birth injuries
Undiagnosed critical congenital heart disease

problems and review of the timeline and interventions that have occurred. This serves as a platform for team members to share critical information and brainstorm as a group to identify potential solutions if resuscitation is not proceeding as anticipated. Recaps serve as brief "time-outs" in the middle of a resuscitation and may help function as a "reset," forcing team members to step outside of their individual concerns and break down silos that may have naturally formed. While this pause may be viewed as loss of critical time during an emergency, recaps are invaluable in sharing information and re-establishing a shared mental model, which re-focuses and re-prioritizes the group to a common goal.

7. Expected emergencies (known fetal anomalies and/or characterizization as a "high-risk" pregnancy) – WEEKS/MONTHS to anticipate and prepare

Through partnerships with obstetrics and maternal-fetal medicine (MFM), neonatal teams are often alerted to the complex, high-risk fetus during pregnancy (see Fig. 1). This allows time to gather clinical information about the anomalies present, follow the growth and development of the fetus, determine the potential impact of anomalies on mortality and short-/long-term morbidities, and have detailed discussions with the families about their values and preferences. After this information is gathered, multidisciplinary teams work together to anticipate and prepare for the high-risk delivery, detailing algorithms for prioritizing interventions based on the clinical scenarios present at birth.

7.1. Gathering information

Improvement in pre-natal imaging and diagnosis allows unprecedented insight into fetal anomalies. In addition to ultrasonography (US), magnetic resonance imaging (MRI) and fetal echocardiography (echo), are additional modalities more commonly utilized to gain greater anatomic and physiologic information about the fetus. This allows obstetric, neonatal and subspecialty teams to better anticipate the potential interventions that may be required and customize approaches to resuscitation.

7.2. Fetal care teams – coordinating information and streamlining care

If DR emergencies are anticipated, transfer of care and delivery at a hospital with high-risk MFM providers, advanced neonatal providers and subspecialty availability is recommended [30–32]. Inclusion of pediatric sub-specialists in the discussion of potential impact on the fetus can provide a holistic view of interventions required, risk of mortality, lifetime morbidities, and potential impact on the family [33].

Given the complexity involved in defining and predicting outcomes in fetal anomalies and the need for multidisciplinary involvement in counseling, planning and management, centers are increasingly establishing fetal care teams to coordinate management of high-risk fetuses and pregnancies [34,35]. Regular, multi-disciplinary discussion of cases maintains shared mental models among large teams with regard to understanding all the problems related to the developing fetus and facilitates prioritizing management [36].

This coordination of care is particularly important for families of fetuses which may have several complex anomalies. In this case, having each subspecialist understand how their "problem" fits into the larger picture, can help limit confusion during counseling, ensuring that the message to the family remains the same from provider to provider. Importantly, this multi-disciplinary support links the continuum of care, allowing smooth transitions from pregnancy, to delivery, through neonatal care and into childhood.

In addition to the obstetrics/MFM, neonatal and sub-specialty providers, ancillary staff are also integral to the overall care of the family and fetus with complex anomalies. These may include social work, child life (to help families frame transmission of information to other children), and palliative care teams. Finally, a central coordinator within the team may serve as a point of contact with families, helping to streamline care, direct questions and dispel further confusion [37].

7.3. Integrating the family into medical decision making and planning with a known, potentially lethal anomaly

As information is gathered and potential interventions and outcomes are anticipated, in depth discussion with the family should also occur. Gathering as many of the sub-specialty teams to meet simultaneously with the family as possible can be helpful to provide a holistic view of management options. Moving beyond just survival, this can provide the family with a more complete perspective on the necessary short- and long-term interventions and help them make personal judgements on the impact these may have on quality of life. This may be critical in helping families come to decisions on goals of care and decisions related to management of the pregnancy and any emergencies that may arise in the DR. Social work and palliative care providers may also be helpful resources.

7.4. Developing a DR resuscitation plan – anticipating potential emergencies

Once information about the fetus/pregnancy have been gathered, the appropriate multi-disciplinary team has been assembled, and the parents have expressed their values and preferences for resuscitation of the newborn, preparing a detailed DR resuscitation plan may begin.

As previously described, this planning should begin with anticipation of all potential problems and emergencies that may arise due to the anomalies described in the fetus. From here, specific equipment should be listed and potential interventions and management strategies in the DR discussed.

Table 6 provides a summary of critical information to gather for planning, specific equipment and potential DR strategies as they related to a sampling of categories of fetal anomalies [38,39]. This is by no means exhaustive and readers should refer to other articles for details of specific management in the DR for particular anomalies of interest.

Once the team has anticipated potential emergencies that may arise, potential DR strategies and a detailed resuscitation plan should be established. Additionally, contingency plans and activation protocols should be reviewed. This information should next be tested and refined in simulation. Once finalized, it can be shared with the larger resuscitation team and reviewed again prior to delivery.

8. Case study: cloacal dysgenesis with uterine duplication anomaly and hydrometrocolpos

A 28-year-old G1P0 woman was referred to our institution for evaluation of a large cystic structure in the abdomen/pelvis identified on fetal ultrasound at 25 weeks gestational age.

Imaging of lesion:

- 27 weeks: Ultrasound performed demonstrated moderate urinary ascites and a midline bi-lobed cystic structure superior to the bladder.

Table 6
Examples of considerations when preparing a delivery room resuscitation plan where emergencies may be anticipated.

Categories of Fetal Anomalies	Critical Information to Gather for Planning	Specific Equipment[a]	Potential DR Strategies
Obstructive Airway Malformations Pierre Robin Cervical teratoma CHAOS	• Upper airway anatomy • Presence of other anomalies • Presence of polyhydramnios • Presence of hydrops	• Specialized equipment required by advanced airway team[b] • Supplies for centesis[c] • Equipment for placement of tracheostomy	• Number/timeframe of attempts at intubation prior to tracheostomy • When to consider centesis if hydrops present
Congenital Cardiac Disorders Pulmonary atresia TGA Hypoplastic left heart	• Anticipated post-natal need for PGE	• Access – emergency UVC • PGE • Normal saline • ECG	• When to consider PGE • When to consider volume to improve systemic perfusion
Thoracic Disorders CDH CPAM BPS	• Risk/severity of pulmonary hypoplasia • Presence of other anomalies • Presence of hydrops	• Orogastric tube (OGT) • Access – emergency UVC • Supplies for centesis • EXIT/ECMO team and equipment readiness	• Ventilation strategy based on thoracic disorder • When to place OGT for abdominal decompression • Ventilation/oxygenation strategies for degree of pulmonary hypoplasia anticipated[d] • When to perform needle thoracentesis • When to consider centesis if hydrops present
Abdominal Wall Defects Gastroschisis Omphalocele	• Size of omphalocele[e] • Extra-abdominal viscera	• OGT • Sterile bag, plastic wrap	• Immediate OGT for abdominal decompression • Consideration of early intubation • Preferred methods of dressing defect in DR to prevent insensible fluid losses/injury to viscera
Skeletal Dysplasia Osteogenesis imperfecta Achondroplasia	• Upper airway anatomy • Risk of pulmonary hypoplasia • Presence of other anomalies	• Supplies for thoracentesis	• Ventilation/oxygenation strategies if pulmonary hypoplasia present When to perform needle thoracentesis • High risk for fracture
Genitourinary Anomalies Bladder exstrophy Cloacal exstrophy	• Presence of other anomalies	• Sterile bag, plastic wrap, dressing • Umbilical tape •OGT	• Preferred methods of dressing defect in DR to prevent insensible fluid losses, injury to viscera or exposure to infection • Replacement of clamp with umbilical tape to prevent injury to bladder
LUTO PUV Urethral atresia	• Onset of oligohydramnios risk/ severity of pulmonary hypoplasia	• Supplies for thoracentesis	• Ventilation/oxygenation strategies if pulmonary hypoplasia present • When to perform needle thoracentesis
Hydrops Fetalis	• Determine underlying cause (treat/ correct if possible) • Assess risk/severity of pulmonary hypoplasia	• Supplies for centesis	• May require thoracentesis, paracentesis and/or pericardiocentesis • Ventilation/oxygenation strategies if pulmonary hypoplasia present • Establish central access early
Sacrococcygeal Teratomas	• Cardiac function (risk of high output cardiac failure) • Presence of hydrops	• Emergency UVC • O-neg blood or volume available • Supplies for centesis	• Risk of membrane rupture and blood loss • When to consider centesis if hydrops present and affecting ventilation
Neuromuscular Disorders X-linked myotubular myopathy CMD	• Presence of polyhydramnios and risk for pulmonary hypoplasia • Presence of contractures	• Supplies for thoracentesis	• Ventilation/oxygenation strategies if pulmonary hypoplasia present • When to perform needle thoracentesis

CHAOS: congenital high airway obstruction, TGA: Transposition of the great arteries, PGE: prostaglandin E, CDH: congenital diaphragmatic hernia, BPS: bronchopulmonary sequestration, LUTO: lower urinary tract obstructions, PUV: posterior urethral valves, CMD: congenital myotonic dystrophy.

[a] Special equipment in addition to standard equipment that should be present at every delivery.

[b] "Advanced airway team" may be pediatric otorhinolaryngology (ENT) and/or anesthesia. Choice of one or both dependent on local practice.

[c] May include pericardiocentesis, thoracentesis or paracentesis depending on presence of hydrops and space involved.

[d] Ventilation/oxygenation strategies in pulmonary hypoplasia may include: use of higher PIP and FiO_2 and use of PEEP. Teams should be aware that newborns with pulmonary hypoplasia are at high risk for developing air leaks and may require needle thoracentesis if there is impairment in ventilation

[e] Giant omphaloceles are associated with respiratory distress and pulmonary hypoplasia.

- 28 weeks: Fetal MRI demonstrated a bilobed cystic structure within the pelvis representing uterine anomaly with associated hydrometrocolpos, bilateral pyelectasis, and moderate abdominopelvic ascites. Lung volumes were diminished, and the amniotic fluid volume was normal to decreased.

Other studies:

- Fetal echocardiogram: single umbilical artery, absent ductus venosus and pericardial effusion (resolved by 31 weeks gestation).
- Amniocentesis: declined.

Social:

- 32 weeks: Family met with Fetal Care Team including MFM, neonatology, pediatric urology and pediatric surgery teams to discuss findings and suspected diagnosis of cloacal dysgenesis with uterine duplication anomaly. Additional findings of pulmonary hypoplasia (and subsequent complications), DR and neonatal interventions were described, as well as severity of potential short-/long-term morbidities.

A follow up MRI performed at 34 weeks gestational age demonstrated that the hydrometrocolpos had increased in size, with severely decreased amniotic fluid volume and severely hypoplastic lungs. The plan was for delivery at 35 4/7 weeks after a betamethasone course.

DR preparation began at 34 weeks gestational age.

- Anticipated problems/emergencies: Given large hydrometrocolpos and worsening compression of lung fields, there was a strong suspicion for pulmonary hypoplasia. If ventilation was poor and heart rate remained low despite intubation, it could be related to upward compression on the diaphragm/lungs or development of pneumothorax. Estimated fetal weight established.

- Equipment required: In addition to standard NRP equipment, other supplies included those for umbilical catheterization and peripheral IV access, thoracentesis (including transilluminator), and placement of a pigtail catheter. Inhaled nitric oxide and high frequency oscillatory ventilator were on standby in the NICU
- Personnel required at the delivery and roles/potential roles included:
  - Neonatal attending ×2 – first as team leader, second available for procedures
  - Neonatal fellow – perform immediate intubation, potential needle thoracentesis
  - Neonatal nurse practitioner – auscultation of heart rate, UVC placement, potential needle thoracentesis
  - Pediatric urology attending and resident – paracentesis for abdominal decompression
  - Pediatric radiology attending – provide ultrasound guidance for pigtail placement
  - Pediatric surgery attending and resident – on standby, backup for paracentesis
  - Neonatal nurse 1 – place ECG and pulse oximeter, first to provide chest compressions if required
  - Neonatal nurse 2 – draw up medications if needed
  - L&D nurse 1 – runner for supplies, liaison for parental updates
  - Pediatric resident – recorder
  - Respiratory therapy – prepare airway supplies, secure airway, take over bag mask ventilation
- Multiple simulations were performed to identify ideal positioning of team members and placement of equipment for interventions in the DR.
- The resuscitation plan included:
  - Initial steps
  - Placement of pulse oximeter on right hand
  - Immediate intubation with 3.5 endotracheal tube
  - Due to pulmonary hypoplasia, use of increased PIPs and higher FiO_2 were anticipated. Team should start at PIP of 25 cmH_2O and increase as needed to "move" the chest. In addition, FiO_2 should be titrated according to pre-ductal saturation targets with the expectation that the infant would likely require rapid escalation in oxygen to 100% initially and gradual titration down with stabilization
  - If heart rate did not improve despite intubation and positive pressure ventilation:
    - Drainage of the hydrometrocolpos would be prioritized if there was adequate chest rise and bilateral air entry was appreciated. In this instance urology would place a pigtail catheter under ultrasound guidance with radiology assistance, and drain the collection until effective ventilation could be achieved
    - Needle thoracentesis would be prioritized if there was poor chest rise and aeration (particularly if unilateral), and the abdomen was soft. Transillumination could be attempted to verify presence of pneumothorax if time allows
  - Needle thoracentesis would be performed if there was persistent hypoxemia with normal/improving heart rate
  - If paracentesis and needle thoracentesis did not result in improvement in heart rate, parents would be informed, and comfort care again offered.

At 35 weeks gestation, the neonatal team met again with the family to review the case and discuss the MRI findings of enlarging uterine mass and significant pulmonary hypoplasia. The parents were counseled that the baby would be intubated immediately after delivery with the possibility of needle thoracentesis and pigtail catheter placement for abdominal decompression if either was thought to be impeding ability to effectively ventilate. After stabilization, the baby would be brought to her side and then quickly taken to the NICU for further management.

8.1. DR course

A female infant was delivered via planned primary cesarean section at 35 4/7 weeks gestation. On brief examination, the infant appeared limp and apneic. There were no grossly dysmorphic facial features or abdominal wall defects. There was a normal labia majora, labia minora, and clitoris with a single perineal opening. Anal atresia was noted.

The newborn was intubated by two minutes of life with initial increase in heart rate from 20s to 70s. Oxygen saturations were in the 30s on 100% FiO_2. The heart rate did not subsequently increase despite appreciable chest rise and bilateral aeration on auscultation. An eight French percutaneous pigtail catheter was placed by urology under ultrasound guidance in the left hemi-abdomen (into the uterus) by six minutes of life, with removal of 150 mL of yellow fluid consistent with urine. Subsequently, the heart rate increased to > 100 beats per minute (bpm) by 13 min of life, without improvement in saturations. Needle thoracentesis was performed on the left chest for persistent hypoxemia and decreased breath sounds, with 44 mL of air removed. Saturations subsequently increased to the mid-80s. Apgar scores were 1/1/3/7 at 1/

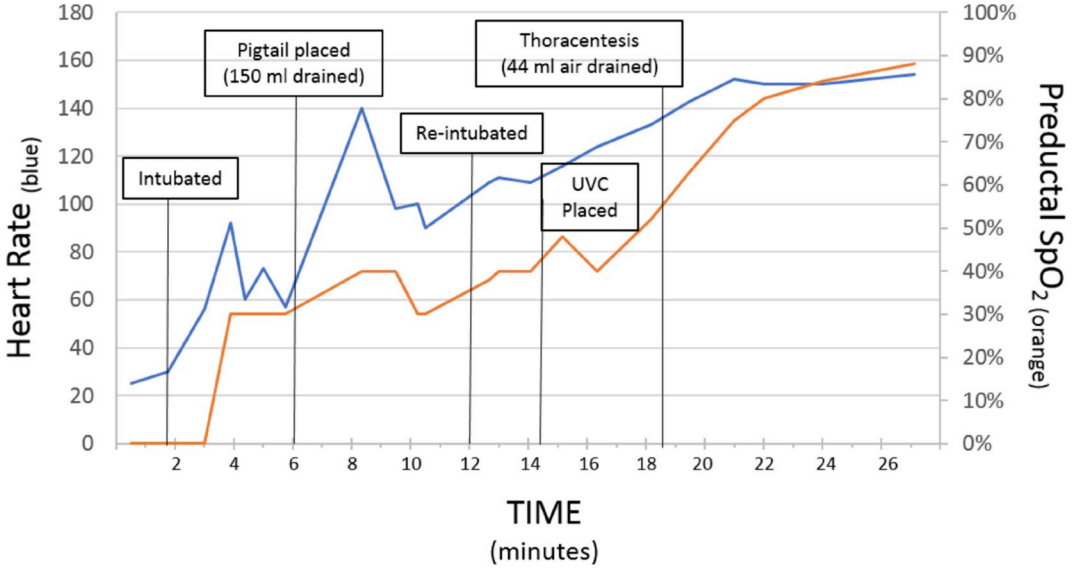

Fig. 2. Heart rate and oxygen saturations with interventions performed during delivery room resuscitation.

5/10/15 min respectively. The newborn was transferred to the NICU at 27 min of life. No chest compressions were performed. Fig. 2 depicts heart rate and oxygen saturation trends in relation to interventions performed during the resuscitation. Without preparation and simulation, it is likely that the delivery room outcome may have been different.

9. Conclusions

Anticipation and preparation for DR emergencies are critical to the successful resuscitation of the high-risk newborn. DR emergencies are often unanticipated. Establishing a shared mental model at critical timepoints before (using a pre-brief), during (using a recap) and after (using a de-brief) resuscitation builds a foundation for effective team management. By leveraging the shared expertise and opinions of all members, the neonatal resuscitation team will more rapidly identify and manage emergencies.

When DR emergencies can be anticipated, such as in the case of the high-risk fetus with identified anomalies, multi-disciplinary collaboration is vital to the anticipation and preparation for potential interventions. In either scenario, the regular review of resuscitations, and the use of simulation to provide a forum for mastery learning and preparation, are fundamental to effective team management and efficient resuscitation in DR emergencies.

Practice points

- Anticipation and preparation are essential to effective management of DR emergencies.
- A shared mental model optimizes communication and collaboration across multi-disciplinary teams.
- A framework of dialogue, checklists, pre-briefing, recaps and debriefing ensure a shared mental model is maintained from pre-delivery preparation through post-resuscitation stabilization.
- Use of regular resuscitation review is critical to ensuring ongoing quality improvement of neonatal resuscitation programs.
- Simulation should be utilized to prepare for unanticipated and anticipated delivery room emergencies.

Research directions

- Assessment of barriers to optimal team functioning in DR emergencies.
- Determine the optimal method of training individuals and teams to maintain shared mental models in emergency situations.

Conflict of interest statement

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