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Circulatory emergencies in the delivery room

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ABSTRACT

The transition from fetal to neonatal life is a dramatic and complex process involving extensive physiologic changes, which are most obvious at the time of birth. Individuals who care for newly born infants must monitor the progress of the transition and be prepared to intervene when necessary. In the majority of births, this transition occurs without a requirement for any significant assistance. If newborns require assistance, the majority of the time respiratory support is all that is required. In some instances, however, there are circulatory emergencies that need to be rapidly identified or there may be dire consequences including death in the delivery room. This chapter will review various pathologies that are circulatory emergencies, and discuss how to assess them. We will also review new technologies which may help providers better understand the circulatory status or hemodynamic changes in the delivery room including heart rate, cardiac output, cerebral oxygenation and echocardiography.

1. Normal transitional changes in circulation

In order to better understand abnormal circulation, it is important to understand the normal transition from fetal to neonatal circulation (Fig. 1, **Panel A and B**). Fetal circulation begins with blood entering the fetus from the placenta through the umbilical vein. The blood is directed towards the left ventricle with shunting across the foramen ovale and ductus arteriosus. Pulmonary blood flow is decreased with constricted pulmonary arteries due to low alveolar oxygen and lung liquid. With the clamping of the umbilical cord, the placenta with its low vascular resistance is removed from the neonatal circulation, resulting in a rise in neonatal systemic blood pressure. At the same time, lung expansion results in release of surfactant and absorption of lung liquid increasing pulmonary blood flow.

These two changes decrease the fetal right-to-left shunt at the ductus arteriosus, resulting in an increasing left-to-right shunt at the ductus arteriosus. Ventilation of the lungs also results in increased blood flow through the pulmonary arteries and lungs. This shift to left-to-right shunting after delivery results in an increase in ventricular stroke volume, which is associated with an increase in cerebral oxygen saturation. With increased lung perfusion and expansion, neonatal oxygenation saturation is increased, which stimulates closure of the ductus arteriosus.

In addition, the increased pulmonary arterial blood flow raises pulmonary venous return to the left atrium and increases left atrial pressure. As the left atrial pressure increases and the right atrial pressure falls, right-to-left shunting across the foramen ovale decreases. Closure of the foramen ovale occurs when the left atrial pressure exceeds the right atrial pressure. Clinically these manifest as a newborn with increasing heart rate and improvement in color and perfusion over the first several minutes after birth.

2. Circulatory emergencies in newborns

Healthy newborns complete the transition from intrauterine to extra-uterine life without difficulty, however about 10% of infants will have impairedadaptation [1]. The most important indicator of a successful transition is an increasing heart rate over the first few minutes. Once an infant has either established their own breathing or requires positive pressure ventilation, they typically have a rising or stable heart rate above 100 beats per minute. The majority of infants that do not have an increasing heart rate at birth are due to inadequate expansion of the lungs due to ineffective ventilation [1]. If an airway has been secured and proper endotracheal placement has been established to achieve effective ventilation of the lungs, persistence of bradycardia constitutes a circulatory emergency and the following conditions should be urgently considered.

Cardiac disease — Infants with severe congenital heart disease may have difficulty with the transition to extrauterine life. The most common are those with cyanotic heart disease who are dependent upon

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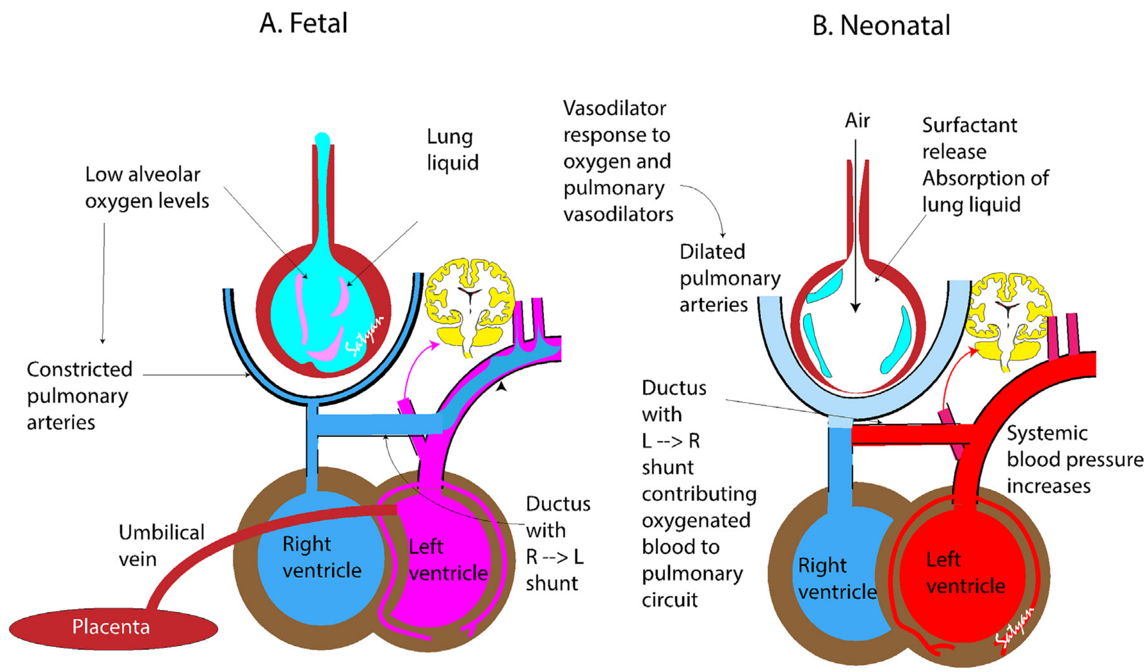

Fig. 1. Normal transition from fetal (panel A) to neonatal circulation. Copyright Dr. S. Lakshminrusimha, UC Davis.

a patent ductus arteriosus for pulmonary or systemic blood flow, or those with severe pulmonary edema due to increased pulmonary arterial blood flow or impaired left ventricular function. The majority of newborns with congenital heart disease do not present with major circulatory issues due to the presence of a patent ductus arteriosus. However, if a closed or restrictive patent ductus is suspected, the clinical team should be prepared to place IV access shortly after birth and administer prostaglandin to ensure ductal patency for critical left and right sided obstructive lesions [1]. Rarely transposition with an intact or restrictive atrial septum can require urgent transport to the catheterization laboratory or even bedside septostomy to ensure adequate atrial mixture.

2.1. *Pneumothorax, pneumomediastinum or pneumopericardium*

Of all of the circulatory emergencies that occur in the delivery room those involving the lungs are the most common and emergent. Pneumothorax occurs more commonly in the newborn period than at any other time. Newborns between 30 and 36 weeks of gestational age or term infants delivered by cesarean section, newborns with meconium aspiration syndrome and those infants requiring extensive resuscitation have an increased risk of pneumothorax. Spontaneous pneumothorax also can occur in a newborn that has not required any resuscitation. The incidence of pneumothorax ranges from 0.07 to 3% [2]. Most air leaks are found in asymptomatic babies who underwent a radiographic examination of the chest as part of a screening series.

Some infants may present with respiratory distress, grunting, nasal flaring, retractions, and tachypnea. There may be asymmetric chest movement but this may not be readily detected. If pneumothorax is large enough, heart sounds may be shifted. Auscultation may reveal decreased breath sounds on the affected side, although normal breath sounds may result from easily transmitted sounds from the contralateral side. In smaller premature infants transillumination of the chest should be considered. If there is bradycardia and/or hypoxia, measures should be undertaken immediately to drain the air (see Fig. 2).

When air is obtained, it is evacuated with the syringe, usually resulting in improvement in the infant's condition. If there is no improvement, one should consider the possibility of a contralateral pneumothorax, requiring drainage. Following stabilization, a decision must be made regarding further therapy. If the infant appears well with no underlying lung disease, no need for mechanical ventilation, and no reaccumulation of the pneumothorax, observation generally is all that is required. If any of these criteria are not fulfilled, it may be necessary to insert a thoracotomy tube for continuous drainage of the intrapleural air. If signs of respiratory distress are present but evaluation allows pneumothorax to be excluded, other types of air leak should be suspected.

Pneumomediastinum occurs with a reported incidence of 25 per 10,000 births in similar circumstances as pneumothorax. The signs and symptoms are generally less severe, and are often limited to tachypnea or mild flaring and retractions [3]. At times, the sternum may appear bulging. Auscultation will reveal distant heart sounds. Treatment generally is limited to careful observation, with aggressive intervention rarely required.

Rarely in the delivery room an infant can present with a pneumopericardium. Clinical features of this air leak include the sudden development of cyanosis, muffled heart sounds, and decreased blood pressure [4]. The severity of this condition varies from asymptomatic to life threatening, and several authors have recommended conservative management unless signs of tamponade are seen. The suspicion of this condition in a newborn whose critical state has not been improved by other therapies mandates rapid pericardiocentesis to reestablish cardiac output. This procedure is described in Fig. 3.

At least half of infants with pneumopericardium will require repeat aspiration, in which case the placement of an indwelling tube with continuous drainage is advocated.

2.2. *Hydrops*

Hydrops fetalis represents a severe condition that generally results in depression of the infant at birth and requires immediate coordinated action in the delivery room. This condition is characterized by total body edema, often with associated collections of fluid in the pleural, pericardial, and peritoneal spaces [5]. Most cases seen today are unrelated to Rh or other blood group isoimmunization, and have a nonimmune etiology. The causes include hematologic conditions causing anemia, structural heart disease or rhythm disturbances causing congestive heart failure, various congenital infections, as well as

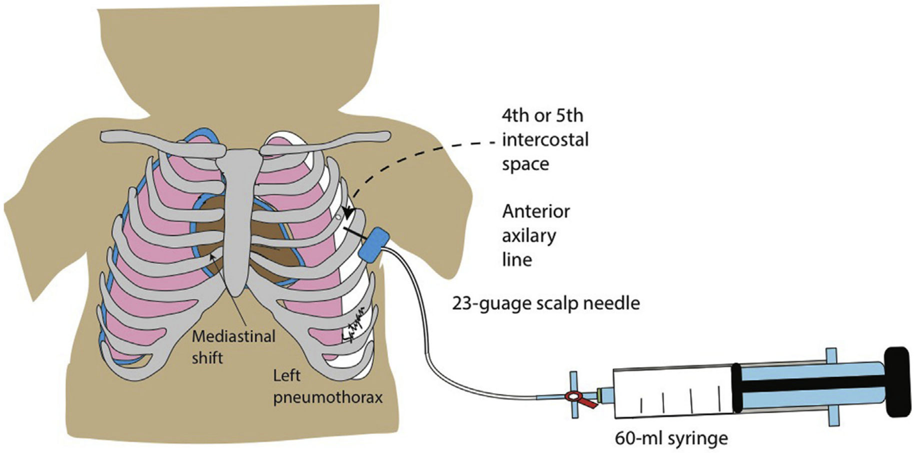

Fig. 2. Treatment of Pneumothorax with needle aspiration. Copyright Dr. S. Lakshminrusimha, UC Davis.

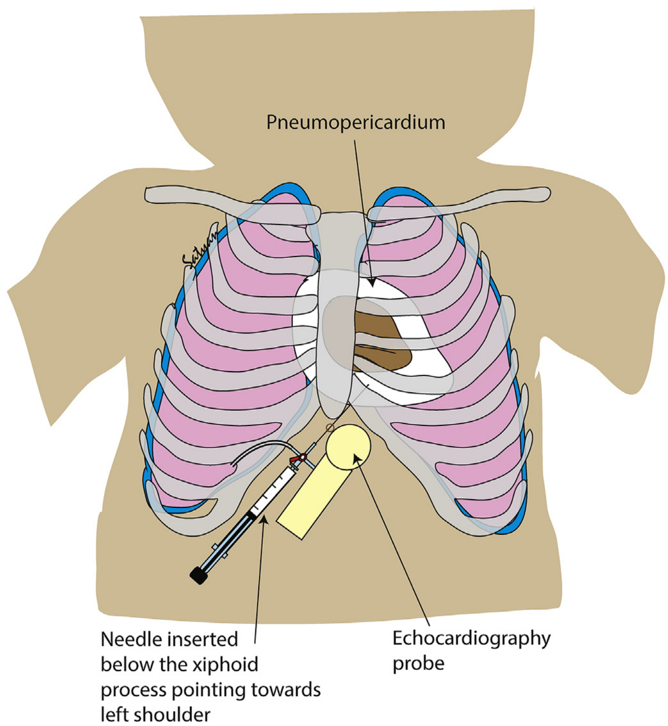

Fig. 3. Treatment of Pneumopericadium with needle aspiration. Copyright Dr. S. Lakshminrusimha, UC Davis.

malformations and chromosomal abnormalities. No single mechanism explains pathogenesis in these conditions. The presence of prematurity, congenital anomalies, or chromosomal disorders has been associated with a diminished prognosis while hydrops due to cardiac arrhythmias has a better outlook. Cases of hydrops related to supraventricular tachycardia have been corrected in utero through maternal treatment with digitalis. In all cases, complete prenatal diagnosis has played a major role in improved survival. The delivery of a hydropic infant should be attended by a team of pediatricians. If prenatal diagnosis or postnatal assessment suggests large effusions, more than one person will be necessary to accomplish rapid and effective resuscitation. Following the general guidelines of resuscitation, the hydropic infant in distress should be quickly intubated to allow rapid establishment of adequate oxygenation and ventilation. Team members should be assigned specific tasks, including central line placement, and drainage of pleural, peritoneal, or pericardial fluid. Diagnoses such as anemia known prenatally or diagnosed at birth, treatment with partial exchange transfusion with O-negative packed red blood cells can be accomplished through umbilical venous and arterial catheters. In any case, the stabilized infant can be taken to the newborn intensive care unit, where a complete evaluation of potential etiologies can be pursued.

2.3. Fetal blood loss

Placental abruption is defined as the premature detachment of the placenta from the uterine wall and occurs in 0.6%–1% of all pregnancies in the Unites States [6]. Placental abruption causes a decrease in the surface area available for oxygen exchange and nutrient and blood supply to the fetus. Newborns born with a placental abruption at delivery are at an elevated risk for neonatal resuscitation, asphyxia, and mortality.

Umbilical cord prolapse is another obstetrical emergency that can have significant neonatal morbidity and/or mortality. It is diagnosed by visualizing/palpating the prolapsed cord outside or within the vagina in addition to abnormal fetal heart rate patterns. Women at higher risk of umbilical cord prolapse include multiparous with malpresentation. Other risk factors include polyhydramnios and multiple pregnancies.

The majority of pregnancies have minimal hemorrhage of fetal blood into the maternal circulation. Rarely, the hemorrhage can be large enough to compromise the fetus resulting in demise, stillbirth, or delivery of a severely anemic infant. The symptoms of a significant fetal-maternal hemorrhage can be subtle, non-specific and difficult to identify. Prenatally the mother may present with a history of decreased or absent fetal movement [7]. Fetal heart rate monitoring will show a sinusoidal pattern, a lack of acceleration and recurrent late decelerations [8]. A sinusoidal fetal heart rate pattern is a category III classification necessitating immediate assessment [9].

Cord avulsion or spontaneous umbilical cord rupture is defined as the disruption of one or more of the umbilical cord vessels at some point between the fetus and the placenta [10]. Significant blood loss can occur and rapid intervention may be necessary to prevent perinatal morbidity and mortality. The majority of cases have been in the setting of patients with a velamentous cord insertion or in the setting of a difficult extraction.

3. Assisting circulation

In newborn infants the need for resuscitative measures beyond assisted ventilation is extremely rare. Additional circulatory assistance can include chest compressions, administration of epinephrine, and volume infusion. In a large urban delivery center with a resuscitation registry, 0.12% of all infants delivered received chest compressions

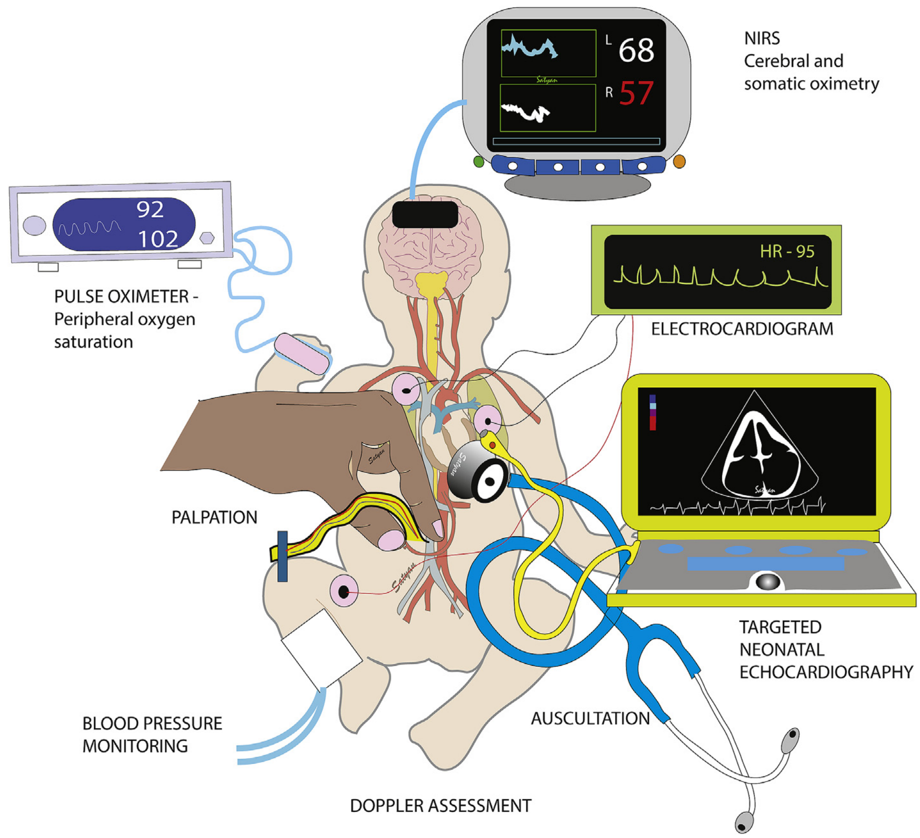

Fig. 4. Methods for circulatory assessment in the delivery room. Copyright Dr. S. Lakshminrusimha, UC Davis.

and/or epinephrine in 1991–1993 [11] and 0.06% of all infants delivered received epinephrine from 1999 to 2004 [12]. Ventilation remains the most critical priority in neonatal resuscitation. However, if adequate ventilation is provided for 30 s, and bradycardia with heart rate < 60 bpm persists, chest compressions are initiated. Further attention to ventilation with the use of increased pressures and/or intubation may be required. Chest compressions are preferably provided with two thumbs on the sternum while both hands encircling the chest [13]. The chest is then compressed in a 3:1 ratio coordinated with ventilation breaths.

Further circulatory support may be necessary if adequate chest compressions and ventilation with 100% oxygen do not result in an increase in heart rate after 60 s. Epinephrine is then indicated as a vasoactive substance which increases blood pressure by alpha-receptor agonism, improves coronary perfusion pressure, and increases heart rate by beta-receptor agonism. Intravenous administration of epinephrine is more likely to be effective than endotracheal administration. The intravenous dose of 0.01–0.03 mg/kg (0.1–0.3 mL/kg of a 1:10,000 solution) is currently recommended. Early placement of an umbilical venous catheter is critical in order to deliver intravenous epinephrine quickly enough to be effective. In order to place an umbilical catheter as quickly as possible it is necessary to have the equipment readily available and to begin the procedure as soon as possible. This could be accomplished by the lead resuscitator assigning the task of placing the catheter as soon as chest compressions are initiated. If there is any prenatal indication that substantial resuscitation will be required, the necessary equipment for umbilical venous catheter placement should be prepared before delivery. Epinephrine may be given by endotracheal tube but the efficacy of this delivery method is not as certain and therefore an increased dose of 0.05–0.1 mg/kg (0.5 mL–1 mL/kg of a 1:10,000 solution) is currently recommended. Epinephrine doses may be repeated every 3 min if heart rate does not increase over 60 beats per minute. Excessive epinephrine may result in hypertension which in preterm infants may be a factor in the development of intraventricular hemorrhage. However, the risks are balanced by the benefit of successful resuscitation in an infant who might not otherwise survive.

If the infant has not responded to all of the prior measures a trial of increasing intravascular volume should be considered by the administration of crystalloid or blood. Situations associated with fetal blood loss are also frequently associated with the need for resuscitation. These include placental abruption, cord prolapse, and fetal maternal transfusion. Some of these clinical circumstances will have an obvious history associated with blood loss whereas others may not be readily evident at the time of birth. Signs of hypovolemia in the newborn infant are non-specific but include pallor and weak pulses. Volume replacement requires intravenous access for which emergent placement of an umbilical venous catheter is essential. Any infant who has signs of hypovolemia and has not responded quickly to other resuscitative measures should have an umbilical venous line placed and volume infusion administered. The most common (and currently recommended) fluid for volume replacement is isotonic saline. A trial volume of 10 mL/kg is given initially and repeated if necessary. If a substantial blood loss has occurred the infant may require infusion of red blood cells to provide adequate oxygen carrying capacity. This can be accomplished emergently with non-crossmatched o-negative blood, with blood collected from the placenta, or with blood drawn from the mother who will have a compatible antibody profile with her infant at the time of birth. Because not all blood loss is obvious and resuscitation algorithms usually include volume replacement as a last resort of a difficult resuscitation, the clinician needs to keep a high index of suspicion for significant hypovolemia so that action may be taken to correct the problem as promptly as possible. Therefore, in situations where the possibility for hypovolemia and need for placental transfusion is known prior to birth it is important to prepare an umbilical catheter, a syringe with isotonic saline and discuss with the blood bank and the delivering physicians the possibility that non-crossmatched blood may be required.

4. Assessing circulation- EKG, NIRS, cardiac output monitoring, echocardiography

There are a number of methods for circulatory assessment (see Fig. 4).

Just as fetal heart rate monitoring can be valuable in identifying emergent perinatal problems such as a prolapsed umbilical cord or asphyxia, heart rate (HR) is the most important clinical indicator to evaluate the overall status of a newborn and is also used to guide any resuscitation efforts. Several studies have demonstrated that HR by auscultation or palpation of the umbilical cord are inaccurate [14–16]. Heart rate from a hand held Doppler correlates reasonably well with electrocardiogram (EKG) and pulse oximetry (PO) heart rates [15,17]. Smartphone based pulse rate applications have also been evaluated [18]. These methods are also most commonly done only for a few seconds at a time and require that an individual stop other procedures to conduct a brief evaluation of heart rate at a time when heart rate and cardiovascular status are in continuous flux. For this reason, continuous heart rate measurements In general are superior to auscultation and palpation. Continuous pulse rate from a pulse oximeter is comparable to that of EKG, but there is an initial stabilization period where the HR may be inaccurate until an adequate wave form is achieved [19]. Several non-contact methods are currently under investigation but are not readily available as a tool to collect continuous HR data, including photoplethysmography and non-contact Doppler radar [20–22]. EKG is a proven technology that provides a reliable HR faster than pulse oximetry [19,23,24]. In addition, one study has shown that pulse oximetry in the first 2 min of life frequently displayed the newborn's HR below 60 beats per minute, while a simultaneous EKG showed the HR greater than 100 beats per minute [25]. The recent guidelines from the International Liaison Committee on Resuscitation recommend the use of a 3-lead EKG for rapid and accurate assessment of a newborn's HR.

Recently, there have been novel tools used in the NICU that are now being studied in the delivery room to monitor the circulatory status of the newborn. The rationale for this is that there may be the potential to identify a circulatory emergency sooner or restore circulation adequately with additional monitoring. The non-invasive nature of these modalities make them ideally suited for the delivery room where central access and other invasive methods may be too time consuming and labor intensive during a resuscitation.

Preterm infants that require extensive resuscitation at birth have a higher rate of intraventricular hemorrhage (IVH) and death [26]. Current methods of monitoring a premature newborn at birth include HR and peripheral arterial oxygen saturation (SpO_2). Neither allows direct assessment of the brain at birth. Non-invasive neural monitoring by Near Infrared Spectroscopy (NIRS) and amplitude integrated electroencephalography (aEEG) has been show to detect differences in early brain injury [27–29]. NIRS may allow for detection of low regional blood flow earlier than blood pressure, lactate, or urine output.

Monitoring in the neonatal intensive care unit (NICU), may include neuromonitoring with aEEG and/or cerebral oxygenation with NIRS. However, monitoring in the delivery room remains minimal. Cerebral oxygenation and aEEG monitoring at birth may predict infants at risk for poor outcomes. A few trials have attempted to bring both aEEG and NIRS into the delivery room but only for monitoring near-term and term infants, many of whom did not require any resuscitation [30,31]. Delivery room monitoring of preterm infants during resuscitation may lead to an improved understanding of how the premature brain responds during this critical time and provide physiological basis for changes in the resuscitation process. These very early, potentially corrective changes in physiology may be able to protect the brain from permanent injury.

Cardiac output monitoring allows for continuous monitoring during transition. One method uses electrical velocimetry to non-invasively measure stroke volume, cardiac output and heart rate using 4 surface EKG electrodes. Two studies have used this technology in the delivery room, one in term infants during vaginal birth with delayed cord clamping [32] and the other was at Cesarean section after the cord was clamped and cut [33]. This technology needs further validation due to its poor correlation with transthoracic echocardiography [34].

Functional echocardiography may allow adopting a physiology-based targeted intervention in sick infants with hemodynamic instability – treating low preload states with volume resuscitation. Bedside echocardiography can be used to assess cardiac function. The systolic function of the left ventricle can be quickly assessed on visual inspection by ‘eye-balling’ the contractility, or quantitatively by measuring the shortening fraction on M-mode. Pericardial effusion can be easily recognized on functional echocardiography, and a timely intervention in presence of cardiac tamponade may improve outcomes.

Echocardiography in the delivery room can provide a real time assessment of cardiac output and hemodynamics [35]. A study completed by Noori et al. demonstrated significant changes in cardiac function, cerebral hemodynamics and oxygenation in 20 subjects in the delivery room. While requiring a significant amount of expertise and training, the increasing number of neonatologists trained to perform cardiac ultrasounds may allow its use to become more common in the near future.

Practice points

- Timely identification of circulatory emergencies is critical in the delivery room
- Preparation of a circulatory emergency should include correct personnel and equipment.
- Newer modalities such as NIRS and echocardiography may improve timely diagnosis of circulatory emergencies but this needs further study.

Conflict of interest

None of the authors have any conflicts.

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