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Interpreting Umbilical Cord Blood Gases: Section 7: Fetal Circulatory Failure, Part IV Case 22: Acute Fetal Hemorrhage with Reperfusion Acidosis

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The mother was a 22-year-old, gravida 1, para 0, aborta 0, with an intrauterine pregnancy at 37 4/7 weeks gestation. She had moderate contractions, and her cervix progressed to seven cm dilated, completely effaced, and with the vertex at zero station with late decelerations on the fetal monitor. In conjunction with a small amount of vaginal bleeding, deep late decelerations ensued, resulting in an emergency cesarean section 20 minutes later. Apgar scores were 0, 0, 0, 0, and 1 at one, five, 10, 15, and 18 minutes, respectively.

Cord blood gas results were as follows:

	Umbilical Vein	Umbilical Artery
pH	7.16	7.11
Pco_2 (mmHg) ***(kPa)***	70 *9.33*	75 *10.00*
Po_2 (mmHg) ***(kPa)***	13 *1.73*	10 *1.33*
BD_{ecf} (mmol/L) **(CSLI)**	4	6

Resuscitation included intubation, bag/tube ventilation with 100% oxygen, chest compressions, ETT epinephrine, UVC epinephrine, and sodium bicarbonate. The infant was pale, poorly perfused, and weighed 3580 g. The placenta was not examined.

Although an umbilical venous catheter was in place, blood could not be drawn freely, and neither a blood gas nor a hematocrit was obtained.

After 60 mL of 5% dextrose in ½ normal saline (D5/½NS) and 35 mL Plasmanate were infused, an arterial blood gas was drawn from the infant.

Results at approximately age 50 minutes were as follows:

	Infant's ABG
pH	6.91
Pco_2 (mmHg) ***(kPa)***	80 *10.67*
Po_2 (mmHg) ***(kPa)***	16 *2.13*
BD_{ecf} (mmol/L) **BD_b (Hgb 5.7)** **(CSLI)**	17 16

The hematocrit from this sample was 17% (Hgb ~ 5.7). After transfusion with 45 mL of PRBCs from an uncrossmatched unit, the hematocrit was 30% (Hgb ~ 10).

Results from the second follow-up arterial blood gas at approximately two hours of age were:

	Infant's ABG
pH	7.28
Pco_2 (mmHg) ***(kPa)***	20 *2.67*
Po_2 (mmHg) ***(kPa)***	84 *11.20*
BD_{ecf} (mmol/L) **BD_b (Hgb 10.0** **(CSLI)**	17 16

A WBC count obtained within the first hour of life did not show an elevated NRBC count. A maternal Kleihauer-Betke test performed several hours later was negative. Three days later, a head ultrasound demonstrated severe bilateral cortical necrosis with no evidence of intracranial hemorrhage. After a detailed discussion with the parents, an agreement was reached to discontinue ventilatory support. The infant died shortly thereafter.

Interpretation

The umbilical venous blood gas sample has moderate respiratory acidosis, while the umbilical arterial blood gas sample has

only mild. Both umbilical venous and arterial blood samples have normal base deficits. Initially, however, the infant is clinically dead. It is not possible for the umbilical arterial blood gas obtained to reflect the situation at the fetal tissue level accurately. At the time of birth, the infant had no discernable heart rate and therefore had no blood pressure. Blood had not been entering the umbilical arteries from the fetus for an undetermined period prior to birth. Therefore, umbilical arterial blood stopped reflecting fetal status when fetal blood pressure fell below the critical pressure necessary for perfusion of the umbilical arteries and other fetal vessels.

During rapid acute blood loss, blood flows preferentially to the area of least resistance, the site of hemorrhage. Under these circumstances, tissue hypoxia is reflected poorly in any fetal vessel as blood is no longer flowing to nor returning from the fetal tissues. Blood drawn from an individual in the process of rapid exsanguination will have normal or near-normal blood gas values.

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Neonatal blood volume was reconstituted initially with D5W/½NS and Plasmanate, a total of 95 mL. This accounts for the initial hematocrit being as low as 17%, as much of this infant's total blood volume had been reconstituted. Shortly thereafter, the blood volume was further reconstituted with 45 mL of PRBCs. The restored circulation enabled the sequestered tissue lactic acid to enter the bloodstream – *reperfusion acidosis*. In the face of a depressed newborn whose clinical condition has been improving, logic suggests that a follow-up base deficit would be similar or improved. When it has deteriorated significantly, suspect reperfusion acidosis. A number of other cases presented in this text have similar findings.

The respiratory acidosis in the umbilical venous gas is not explained by acute fetal hemorrhage, as this gas reflects primarily the uteroplacental unit, not fetal integrity. Likely, the respiratory acidosis was secondary to a brief terminal event associated with anesthesia and delivery, as there was not yet any metabolic acidosis (expected base deficit of 6).

Unfortunately, the placenta was neither examined in the delivery room nor by the pathology department. Nonetheless, a ruptured vasa previa seems to be the most likely cause of the clinical and laboratory information. The fetus has had a large recent blood loss. A negative Kleihauer-Betke test on the mother rules out significant fetal-maternal hemorrhage. The absence of an elevated NRBC count in the infant excludes more chronic hemolysis or blood loss. The head ultrasound examination three days after birth did not demonstrate hemorrhage. What is described as a "small amount" of vaginal bleeding can amount to a large hemorrhage for the fetus if the blood is fetal in origin.

During marked fetal hypovolemia and consequent cardiac standstill, circulation to the brain ceased and resulted in necrosis.

At term, the fetal-placental unit has a blood volume of approximately 125 mL/kg of newborn weight. (1,2) Using the birth weight of 3580 g and 125 mL/kg to calculate the total fetal-placental blood volume results in approximately 448 mL (3.58 x 125 = 448). The lower end of the range for hematocrit in full-term infants is approximately 42%, although the upper end may be as high as 65%. (3) More than half of the calculated fetal-placental blood volume would have to be lost for the hematocrit to have dropped to 17%. A "small amount" of vaginal bleeding could easily amount to more than 100 mL, inconsequential to the mother but potentially catastrophic to the fetus. Likely, additional blood was lost and unobserved during preparation for emergency cesarean delivery.

BD_{ecf} does not take hemoglobin into account, while BD_b does. However, substituting either 5.7 gm/dL hemoglobin (Hct 17%/3 = 5.7 gm/dL) in the first followup blood gas or 10 gm/dL hemoglobin (Hct 30%/3 = 10 gm/dL) in the second followup blood gas, makes very little difference in the BD_bs. Only when Hgb is truly extreme, do significant differences occur.

Much has been made about the value of an Apt test in differentiating fetal from maternal blood. This test was designed to differentiate maternal from fetal blood in emesisor stoolsof newborn infants, but has also been applied to vaginal bleeding. However, if vaginal bleeding is due to loss of fetal blood, long before the results of an Apt test return from the laboratory, the fetus will have exsanguinated. Bedside testing, if available, might provide information in a timelier manner. Usually, electronic fetal monitoring provides the timeliest information as it will quickly reflect major fetal hemorrhage.

"Many infants with severe asphyxia have poor circulation at the time of birth. Blood does not circulate freely to the fetal tissues. It is not until a good heart rate, and at least a reasonable blood pressure is restored that oxygen is brought to the tissues in sufficient quantity to restore normal metabolism at the tissue level. As normalizing circulation and metabolism are restored to the newborn's tissues, lactic acid is cleared into the central circulation."

Many infants with severe asphyxia have poor circulation at the time of birth. Blood does not circulate freely to the fetal tissues. It is not until a good heart rate, and at least a reasonable blood pressure is restored that oxygen is brought to the tissues in sufficient quantity to restore normal metabolism at the tissue level. As normalizing circulation and metabolism are restored to the newborn's tissues, lactic acid is cleared into the central circulation. Depending on when a follow-up blood gas is obtained from the infant, the worsening metabolic acidosis may not be documented. If the first follow-up blood gas from the infant is not drawn soon enough, the documentation of worsening metabolic acidosis may be missed entirely.

The second follow-up blood gas obtained approximately 70 minutes after the first follow-up blood gas had the same base deficit as the first. In the absence of significant base deficit improvement, fetal heart failure should be seriously considered. It would not be unexpected for this infant to have heart failure following such catastrophic events. One could have considered a partial exchange transfusion with PRBCs rather than a straight transfusion. Obtaining a central venous pressure prior to transfusing the PRBCs might have been instructive.

Finally, how long should resuscitation continue without a heart rate? In 2011, the American Academy of Pediatrics stated in their Textbook of Neonatal Resuscitation, (4) "If you can confirm that no heart rate has been detectable for at least 10 minutes, discontinuation of resuscitation efforts may be appropriate. Current data indicate that, after 10 minutes of asystole, newborns are very unlikely to survive, and the rare survivors will have a severe disability. The decision to continue resuscitation efforts beyond 10 minutes with no heart rate should take into consideration factors such as the presumed etiology of the arrest, the gestational age of the baby, the presence or absence of complications, the potential role of therapeutic hypothermia, and parents' previously expressed feelings about the acceptable risk of morbidity."

"The "right" thing to do is still unclear or at least challenging to carry out. It is difficult to terminate resuscitation as early as 10 minutes following delivery because of perceived or actual psychological pressure to continue. This pressure comes from the obstetrical team that just completed an emergency cesarean delivery, from the parents' frequent desire for the resuscitators to continue to try for a more extended period, and/or from the internal emotional pressure of members of the resuscitation team."

Largely, this last statement is based on an instructive article published in 1991 by Jain et al. (5) Of 58 infants whose Apgar scores were 0 for 10 minutes or more following delivery and who eventually had a heartbeat, only one survived to go home from the hospital; that lone survivor developed cerebral palsy. A 2009 article by Laptook et al. (6) reported 25 infants whose Apgar scores were zero 10 minutes after birth and had total body cooling. Six of these infants (24%) survived and were normal or had only a mild disability. A 2020 article by Zhang, Friedman, and Strand (7) from a chart review of 49,876 infants born between 2010 and 2017 whose ten-minute Apgar score was 0 or 1, 172 were identified. "Of these, 133 did not receive resuscitation and died while receiving comfort care. Of the 39 resuscitated newborns, 15 (38%) achieved a return of spontaneous circulation at an average of 20 minutes. Thirty-two of these newborns died (82%) within 24 hours. The average time of the return of circulation for survivors was 17.8 minutes. Death or severe neurologic disability at 15-24 months of age was present in 92% (36-39) of resuscitated infants." The "right" thing to do is still unclear or at least challenging to carry out. It is difficult to terminate resuscitation as early as 10 minutes following delivery because of perceived or actual psychological pressure to continue. This pressure comes from the obstetrical team that just completed an emergency cesarean delivery, from the parents' frequent desire for the resuscitators to continue to try for a more extended period, and/or from the internal emotional pressure of members of the resuscitation team. During the resuscitation, there is no time to have a considered discussion.

Key Points:

- During rapid acute blood loss, blood circulates preferentially to the area of least resistance, the point of blood loss, and poorly to the tissues.
- Umbilical artery samples will not accurately reflect fetal tissue status during acute fetal hemorrhage.
- In the face of a depressed newborn whose clinical condition is improving, a follow-up neonatal blood gas would be expected to have an improved base deficit from the umbilical artery sample. When it has deteriorated, suspect reperfusion acidosis.
- It is only following reperfusion that the full extent of metabolic acidosis at the tissue level becomes apparent.

References:

1. *Usher R, Shephard M, Lind J. The blood volume of the newborn infant and placental transfusion. Acta Paediatr 1963;52: 497-512.*
2. *Gruenwald P. Growth of the human foetus. In: McLaren A (ed): Advances in reproductive physiology. New York, Academic Press, 1967, p279.*
3. *Jopling J, Henry E, Wiedmeier SE, Christensen RD. Reference ranges for hematocrit and blood hemoglobin concentration during the neonatal period: Data from a multihospital health care system. Pediatrics 2009,123:e333-7.*
4. *American Academy of Pediatrics: Textbook of Neonatal Resuscitation, 6th ed. 2011, Ethics and care at the end of life, p292.*
5. *Jain L, Ferre C, Vidyasagar D, Nath S, et al. Cardiopulmonary resuscitation of apparently stillborn infants: Survival and long-term outcome. J Pediatr 1991;118:778-82.*
6. *Laptook AR, Shankaran S, Ambalavanian N, Carlo WA, et al.; Hypothermia Subcommittee of the NICHD Neonatal Research Network. Outcome of term infants using apgar scores at 10 minutes following hypoxic-ischemic encephalopathy. Pediatrics 2009;124:1619-26.*
7. *Zhang SQ, Friedman H, and Strand ML. Length of resuscitation for severely depressed newborns. Am J Perinatol 2020, 9:933-8.*

Disclosures: The author has no disclosures

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