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Interpreting Umbilical Cord Blood Gases

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Introduction

The purpose of this series is to assist clinicians in better understanding the indications for testing umbilical cord blood gases, in recognizing the pitfalls involved in collecting and handling specimens, and incorrectly interpreting umbilical cord blood gas values. Most of the text comes from my book: Interpreting Umbilical Cord Blood Gases: For Clinicians Caring for the Fetus or Newborn, 2nd edition, published in 2012.

Some areas have been altered for clarity, and not all of the book will appear in this or future installments.

To illustrate these points, I use a series of clinical cases drawn from actual experience with patients. The information is presented by category, and most often each successive case within the category is of increasing complexity. The care provided was not necessarily optimal or even acceptable. As with every endeavor, regular practice produces better results. In many situations, more than one interpretation of umbilical cord gases is possible. Of critical importance is the reasoning behind the interpretations. In general, much additional information is provided, both antenatal and postnatal, along with the blood gas results. Of course, not all of this information is available as the baby is being delivered; however, the goal is the correct interpretation of cord blood gas results. It is important to make sense of the data, not simply to note the presence of respiratory, metabolic, or mixed acidosis. Fairly often, this requires integrating information about the fetal monitoring strip, details of the delivery, the follow-up blood gas results taken directly from the infant, and other post-delivery information.

In each example, the clinical and laboratory data are presented first, with my interpretation presented on the following page. This will allow readers to compose their thoughts prior to reading my conclusions and, more importantly, to develop the reasoning behind them. Some of the clinical presentations occurred many years ago and, not unexpectedly, the standard of care has evolved. For example, initiating use of 100% oxygen as a standard part of resuscitation and use of sodium bicarbonate to correct a base deficit are no longer recommended. Nonetheless, in many of the cases presented, these therapies were employed. Additionally, the clinical expertise of the care providers varied from excellent to poor. Therefore, one should not assume that the care provided represents the state of the art.

The objectives of this text are to help the reader to:

(1) Become familiar with normal umbilical cord blood gas values;

(2) Understand the usual relationship between pH and blood gas values found in the umbilical vein and the umbilical artery;

(3) Recognize how best to interpret the results when technical problems have occurred;

(4) Recognize patterns of abnormal umbilical cord blood gas values and understand their pathophysiology;

(5) Recognize when asphyxia has been associated with delivery and when it has not;

(6) Be able to decipher even complex issues in the interpretation of umbilical cord blood gas results, and,

(7) To boldly interpret where no one has interpreted before.

Following each of the installments, "Key Points" will be listed.

In my experience, clinicians often ignore the results of umbilical cord blood gas values or, at most, simply record them. It is rare that a clinician comments on the results or offers an interpretation. No blood gas value, or other test result for that matter, is self-explanatory; every test result requires clinical validation. I hope this text encourages readers to think about the results and then record their interpretations. This information will help clinicians on both the obstetric and neonatal sides understand the underlying physiology and pathophysiology that contribute to umbilical cord blood gas values. This understanding may assist in improving the outcome of future pregnancies on the obstetric side while helping the immediate care of the newborn on the neonatal side, especially if i-STAT blood gases are run in the delivery room. Although in the United States millimeters of mercury (mmHg) are used as the unit of measure for PCO2 and PO2, many other countries use kilopascals (kPa) as the unit of measure. Accordingly, both units are provided in all tables.

When to Order Cord Gases

The frequency of umbilical cord blood gas sampling ranges from almost universal to almost never. Routine universal sampling will not miss any important abnormalities and has the advantage of providing maximal experience and enhanced skills to those who draw blood for cord gases. The cost for this approach is not great, likely representing only the cost of materials and reagents, as no additional personnel are necessary. A four-year observational study of universal cord blood gas and lactate analysis was conducted at the only Western Australian tertiary level obstetric hospital.

Results suggest that the introduction of universal paired cord blood gas analysis may have resulted in improved perinatal outcomes independent of obstetric intervention. The authors postulate that regular, objective feedback via cord blood gas results close to the time of delivery may positively influence future obstetric management. I favor this approach.

If universal cord gas analysis is not adopted, a more modest approach is to establish criteria for drawing samples that are mutually agreed upon by the obstetrical and neonatal-pediatric services. The American Congress of Obstetricians and Gynecologists suggests that physicians should "attempt to obtain venous and arterial blood cord samples in circumstances of cesarean delivery for fetal compromise, low 5-minute Apgar score, severe growth restriction, abnormal fetal heart rate tracing, maternal thyroid disease, intrapartum fever, or multifetal gestation." Very similar criteria used for many years at Cedars-Sinai Medical Center in Los Angeles are as follows:

1) All infants perceived to have had non-reassuring fetal heart rate tracings or other evidence of concern for fetal well-being, irrespective of Apgar score or other delivery room evaluation;

2) All infants with Apgar scores of 6 or less at any time; and

3) Any infant for whom anyone present at delivery deems cord blood gases necessary.

If cord blood gases are drawn in the delivery room and run with i-STAT, results may directly and positively affect immediate care of the newborn. Additionally, results may be directive in the triage of the baby.

Obtaining Cord Gas Samples

A 10-20 cm segment of the umbilical cord is clamped immediately following delivery with two adjacent clamps near the neonate and two adjacent clamps nearer the placenta. Cutting between each of the two sets of adjacent clamps then separates this segment. Placing an additional clamp midway between the other two has been suggested so that a second set of gases may be drawn if the first set turns out to be unsatisfactory.

Typically, blood for umbilical cord gases is obtained by inserting a short, small-gauge needle attached to a plastic syringe into the umbilical vein and a separate needle with a syringe attached into an umbilical artery. A short, small-gauge needle permits optimal control with minimal injury to the vessels. There is a risk of RBC lysis if the needle gauge is too small or the syringe is drawn up too quickly. This might lead to an artificially elevated lactate level. Alternatively, umbilical venous and arterial samples may be drawn from the vessels on the chorionic plate (see, Analyzing Cord Gases below, regarding the need for rapidly obtaining these samples). Drawing blood from this site is very simple as it is similar to starting an IV in a large vessel without any intervening tissue that might make visualization difficult. Distinguishing veins from arteries is not difficult as veins are larger and less muscular than arteries. Additionally, arteries reliably cross over veins.

A complete blood gas analysis can be performed on samples as small as 0.1 cc; however, 0.3 cc or more is optimal as it permits retesting, if necessary.

Historically, there has been a discussion about the impact of excessive heparin within the collecting syringe on cord blood gas values. The pH of heparin is about 7.0. As PCO2 and PO2 approach room air values, approximately 0.4 mmHg and 160 mmHg, respectively, excess heparin will result in decreasing pH and PCO2 values, worsening base excess and increasing PO2 in umbilical cord blood. This issue has become moot, as syringes used for blood gas analysis today come pre-heparinized with powdered heparin. If the blood gases are to be analyzed immediately after being drawn, heparin is unnecessary.

Analyzing Cord Gases

Umbilical cord blood gases should be analyzed as soon as possible after birth. In practice, the attention required by the mother or newborn may preclude attention to the cord blood gas sample. No clinically important changes in blood gas values are seen in a doubly clamped , umbilical cord at room temperature, , or drawn into a plastic syringe and left at room temperature, , for 60 minutes following delivery. Blood analyzed from vessels in the chorionic plate, however, must be drawn into a syringe quickly, as significant deterioration of values (increasing respiratory and metabolic acidosis) occurs when there is a delay of more than 15 minutes following clamping the cord.12 Presumably, blood in the chorionic vessels deteriorates more rapidly because it is in juxtaposition to a dense collection of metabolically active tissue in the placenta. The cord, in contrast, is mostly composed of the umbilical vessels themselves and metabolically inactive Wharton's jelly. Perlman et al. had reported significantly "better," although clinically insignificantly different, umbilical artery values when samples were obtained from the cord within 10 cm of the newborn compared to specimens obtained within 10 cm of the placenta. These differences also may represent faster sample degradation when in close proximity to the cell-rich site of the chorionic plate or perhaps actual contamination of cord blood with blood in the adjacent chorionic plate.

Blood gases stored on ice and not analyzed for many hours are still capable of providing useful and relevant data. Chauhan et al. studied umbilical arterial cord blood gas values from 23 infants stored in pre-heparinized syringes kept on ice for up to 60 hours. Separate equations were derived that permit calculation of original pH and base excess values from the time of birth. As expected, over time, pH falls, and base excess becomes increasingly negative.

When Cord Gases Do Not Reflect Fetal Condition

It has been argued that a newborn with no signs of life, whose fetal heart rate had been at approximately 60 bpm for 15 minutes or more prior to delivery, has not been asphyxiated because umbilical cord blood gas values are normal or near normal. You should never accept an umbilical cord blood gas as correctly reflecting the condition of an infant when your common sense tells you it does not. There are reasons for noncorrelation (especially of umbilical venous cord gases) including terminal fetal bradycardia secondary to either cord occlusion or fetal heart failure, and acute fetal hemorrhage. Sometimes we may have sufficient insight to explain the noncorrelation, and sometimes we may not. However, even when we are unable to explain confusing data, this does not mean that no explanation exists, only that our understanding of the data available is not sufficient to do so.

The best correlation between umbilical cord blood gas values and fetal acid-base status exists when blood is freely exiting the umbilical vein and entering the umbilical arteries. In other words, the fetal blood pressure must be adequate to perfuse the umbilical arteries, and the cord must not be occluded. Umbilical vein occlusion occurs much more easily than umbilical artery occlusion. Typically, in cord occlusion, both vein and arteries are occluded initially. Occlusion of the umbilical arteries results in arterial hypertension and reflex fetal bradycardia. If the occlusion continues, arterial hypertension may overcome the occlusive force, resulting in a net transfer of blood to the placenta as the umbilical vein remains occluded. Failing to relieve the obstruction to flow, the fetus becomes progressively asphyxiated, oxygen supply to the heart becomes inadequate to support forceful contractions, blood pressure falls and eventually becomes insufficient to perfuse the umbilical arteries. Once this occurs, an umbilical artery blood gas sample progressively fails to reflect a continuing deterioration of the acid-base status of the fetus.

Umbilical cord venous blood gas samples should not be expected to accurately reflect fetal status following cord occlusion with terminal fetal bradycardia. Additionally, umbilical cord arterial blood gas samples will not fully reflect fetal tissue acidosis when fetal circulation is poor or non-existent at birth. These potential causes of poor correlation between umbilical cord arterial blood gas values and blood gas values at the fetal tissue level should not lead to the notion that umbilical cord blood gas values cannot be relied upon. The overwhelming majority of newborns have both umbilical cord venous and arterial blood gas values that accurately reflect uteroplacental and uteroplacental-fetal status, respectively.

An umbilical cord arterial blood gas represents the mixed venous return of all fetal tissues and does not indicate the acid-base status of any specific tissues. Indeed, severe intracellular acidosis of a specific fetal structure may not be detected in the umbilical artery sample if there is no venous return from that structure; an example would be an ischemic area resulting from a cerebral infarct.

Lastly, a fetus might have sudden ventricular fibrillation or other rapidly fatal arrhythmias. Blood in the umbilical cord would abruptly cease flowing and could result in perfectly normal umbilical venous and arterial blood gas values and a clinically dead newborn. Critically ill newborns who are already severely acidotic and moribund may have terminal arrhythmias. Most neonatologists have almost no familiarity with defibrillators, suggesting the extreme rarity of ventricular fibrillation. Therefore, this scenario must certainly be quite rare.

Fetal Heart Rate Present / Neonatal Heart Rate Absent

Practitioners who regularly attend high-risk deliveries will recognize the occasional scenario of a delivery in which the fetal heart rate was present prior to delivery, but the neonatal heart rate is absent after delivery. In the usual situation, there has been a "crash" cesarean section done for severe fetal distress. At delivery, the infant has an Apgar score of 0. Some of these infants are successfully resuscitated, and some are not. Yet all of these infants had a recorded heart rate shortly before delivery.

The fetal heart rate is recorded by either a Doppler device or by a direct fetal electrode. The Doppler device evaluates fetal heart rate by detecting motion of the fetal heart, especially the valves, and converting the detected beats into a calculated heart rate. It does not differentiate a forceful heartbeat from a slight twitch. A minimal contraction would not be expected to generate any significant cardiac output. At birth, the neonatal heart rate typically is evaluated by auscultation, palpation, or observation (seeing heart movement on a quiet chest). A very slow heart rate is frequently very soft or even inaudible.

Furthermore, one might need to listen carefully in a quiet environment (no artificial ventilation, no chest compressions, or excessive noise) for 10-20 seconds to be sure of these findings. In the emergency atmosphere that exists in all such situations, this luxury is often unavailable. The stroke volume may easily be so low as to generate no palpable pulse at all. The very slight heart movement that might be visible on a quiet chest is not discernable on a chest that is moving with each artificial breath. Practically, there is likely little physiologic difference between a non-beating heart and one in which the movement is so slight that it goes undetected by physical exam.

A direct fetal electrode detects electrical activity generated by the fetal heart. However, there is no assurance that electrical activity is translated into mechanical activity. Under severely hypoxic conditions, electromechanical dissociation (also known as pulseless electrical activity) is not rare. Patients with this condition have an especially poor survival rate.

Occasionally, the fetal monitor (especially if the tracing appears "normal") may have been tracking the maternal heart rate. , , Helpful signs that the heart rate being tracked is maternal rather than fetal include: a maternal heart rate similar to the rate in the tracing, an abrupt change in the baseline rate or rhythm associated with a discontinuity in the tracing, or a rise in heart rate associated with maternal pushing. To distinguish maternal from fetal heart rate recordings, the mother's pulse may be taken and compared with the electronic fetal monitor tracing. If they are very similar, the tracing may be maternal.

Key Points

- Blood from the umbilical vein is preferentially channeled through the foramen ovale providing better-oxygenated blood to the fetal heart and brain.
- Umbilical venous blood reflects uteroplacental status.
- Umbilical arterial blood reflects fetal as well as uteroplacental status.
- Leaving umbilical cord blood left double clamped in an umbilical cord or a syringe at room temperature for up to 60 minutes, results in no clinically important changes in blood gas values.
- Typically, umbilical cord venous blood gas samples would not be expected to accurately reflect fetal status following terminal fetal bradycardia associated with either cord occlusion.
- Umbilical cord arterial blood gas samples will not fully reflect fetal tissue acidosis when fetal circulation is poor or non-existent at birth.
- Severe intracellular acidosis of a specific fetal structure may not be detected in the umbilical artery sample if there is no venous return from that structure.
- The great majority of newborns have umbilical venous and arterial blood gas samples that accurately reflect fetal status.
- You should never accept an umbilical cord blood gas as correctly reflecting the condition of an infant when your common sense tells you it does not.
- Many infants with low Apgar scores have normal or near-normal umbilical arterial blood gas values.
- Occasionally, an infant is delivered without an apparent heartbeat when a fetal heart rate was recorded just prior to delivery. Either an unobservable, feeble heart contraction or electromechanical dissociation (pulseless electrical activity) explains this apparent non sequitur. Alternatively, the fetal monitor may have been tracking the maternal heart rate.

Below are normal umbilical cord blood gases. These are the values that will be used in future umbilical cord blood gas examples. Please retain this page.

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Normal Umbilical Cord Blood Gases		
	Venous Blood Normal Range (Mean ± 2SD)	**Arterial Blood Normal Range (Mean ± 2SD)**
pH	7.25 – 7.45	7.18 – 7.38
P_{CO_2} (mmHg) (kPa)**	26.8 – 49.2 / 3.57 – 6.56	32.2 – 65.8 4.29 – 8.77
P_{O_2} (mmHg) (kPa)**	17.2 – 40.8 / 2.29 – 5.44	5.6 – 30.8 / 0.75 – 4.11
HCO_3^- (mmol/L)	15.8 – 24.2	17 – 27
BD* (mmol/L)	0 to 8	0 to 8

Table

Reprinted with permission from Elsevier, in part from Yeomans ER, Hauth JC, Gilstrap LC III, Strickland DM. Umbilical cord pH, P_{CO_2}, and bicarbonate following uncomplicated term vaginal deliveries Am J Obstet Gynecol 1985;151:798-800.

Data are mean values ± 2 standard deviations (SD).

* Base deficit, estimated from data.

** 1 kPa = 7.50 mmHg; 1 mmHg = 0.133 kPa

Note: “Normal” is arbitrarily defined as the mean ± two times the standard deviation (approximately 95.4% of a normally distributed population).

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