Interpreting Umbilical Cord Blood Gases: Technical Issues: Part II

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Case 4: Blood Gas Samples Drawn from the Same Vessel

The mother was a 31-year-old, gravida 4, para 0, aborta 3, with an intrauterine pregnancy at 42 0/7 weeks by fair dates (20-week sonographic scan with uncertain last menstrual period). (1)

She presented in active labor with ruptured membranes. The fetus was in a breech position. The patient was taken for a primary cesarean section. At delivery, there was a problem delivering the aftercoming head. Apgar scores were 3 and 8 at one and five minutes, respectively.

Cord blood gas results were as follows:

	Umbilical Vein	Umbilical Artery
pH	7.19	7.18
Pco_2 (mmHg) *(kPa)*	66 *8.80*	68 *9.07*
Po_2 (mmHg) *(kPa)*	14 *1.87*	13 *1.73*
HCO_3^- (mmol/L)	25	25
BD (mmol/L)	5	5

Interpretation

The umbilical vein sample's pH is mildly depressed, the PCO_2 moderately elevated, the PO_2 mildly decreased, and the base deficit is normal. The umbilical artery sample pH is normal, the PCO_2 mildly elevated, and the PO_2 and base deficit are normal. Therefore, there is moderate respiratory acidosis in the venous sample and a mild respiratory acidosis in the arterial sample. All the "rules" of the relationship between umbilical venous and arterial samples are met (the venous sample *always* has a higher pH, a lower PCO_2, and a higher PO_2). Yet, it seems obvious that these two samples cannot represent samples of both the umbilical vein and the umbilical artery because the values are almost identical. The only additional finding that could have made this conclusion even more apparent would be if one of the three measured parameters (pH, PCO_2, PO_2) disobeyed the "rules" of relationship. One does not need any formula or additional evaluation process to interpret this set of cord blood gases correctly. However, there are times that the correct interpretation is not as clear (see next case).

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Whenever umbilical venous and arterial pH values are close, but not identical, one also must consider the possibility that one sample consists of mixed venous and arterial blood (most commonly, the needle sampling the artery slips through into the vein behind it). However, the interpretation remains the same, i.e., and two vessels have not been successfully sampled.

In the example above, either an umbilical vein or an umbilical artery was sampled twice. As it is much easier to sample blood from the umbilical vein, it is more likely that both samples are venous, although the values are closer to normal for an umbilical artery sample. The question really becomes, "Was the easier to sample vessel sampled twice, or was the more difficult to sample vessel sampled twice?" The betting odds are with the vein.

In some hospitals, in a cost-containment effort, only an umbilical artery sample is obtained. However, *unless both umbilical venous and umbilical arterial samples are obtained, one cannot be certain that the only sample obtained is indeed from an umbilical artery.* Riley and Johnson (2) suggest looking at the color of the blood samples to ascertain that both venous and arterial samples have been obtained. If the color looks the same, the samples have probably been drawn from the same vessel.

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It has been suggested that an umbilical venous sample is a good proxy for an umbilical arterial sample as the relationship between these two samples is known and is within a certain range. For example, one would expect the umbilical arterial pH to be between 0.04 and 0.10 lower than the pH in the umbilical venous sample, (3,4) (see next case). This is true in normal, non-asphyxiated newborns and even in those newborns who are depressed secondary to uteroplacental insufficiency. However, when the fetus/newborn has issues with cord occlusion and associated terminal bradycardia (5-9) (a relatively common problem … cord occlusion with terminal fetal bradycardia), or with fetal heart failure (10) (a relatively rare problem … fetal circulatory failure), an umbilical arterial sample may have values that are much worse than those in the umbilical venous sample.

Key Points

- When umbilical venous and arterial blood gas samples are almost identical, or if some, but not all of the matched pHs, PCO_2s or PO_2s do not obey the "rules" of relationship, it is clear that the samples come from the same vessel. If all of the matched parameters are opposite to the "rules" of relationship, suspect the samples have been mislabeled (see Case 6). As the umbilical vein is much easier to sample than the umbilical artery, usually, the umbilical vein is the vessel that has been sampled twice.
- Unless both umbilical venous and umbilical arterial samples are obtained, one cannot be certain that a single sample is from an umbilical artery.
- An umbilical venous sample may be a reasonable proxy for an umbilical arterial sample in normal, non-asphyxiated newborns or in newborns depressed secondary to uteroplacental insufficiency.
- In newborns depressed secondary to cord occlusion with terminal fetal bradycardia or fetal heart failure with terminal fetal bradycardia, the umbilical arterial cord gas values may be much worse than those in the venous sample.

Case 5: Blood Gas Samples from One Vessel or Two?

The mother was a 24-year-old, gravida 2, para 0, aborta 1, with an intrauterine pregnancy at 38 1/7 weeks. (1) The mother had spontaneous rupture of membranes with egress of clear fluid and was in labor at the time of admission. The FHR showed non-repetitive, moderate variable decelerations with an occasional severe variable deceleration. After one hour, the mother was completely dilated, completely effaced, with the vertex at +3 station. She pushed for one hour and was taken to the delivery room where the fetus had a deceleration to 60 bpm lasting for one minute. The infant delivered one minute later with Apgar scores of 8 and 9 at one and five minutes, respectively.

Cord blood gas results were as follows:

	Umbilical Vein	Umbilical Artery
pH	7.28	7.25
Pco_2 (mmHg) *(kPa)*	47 *6.27*	52 *6.93*
Po_2 (mmHg) *(kPa)*	29 *3.87*	18 *2.40*
HCO_3(mmol/L)	22	22
BD (mmol/L)	5	5

Interpretation

Both cord blood samples are entirely normal. The issue is, "Are these two blood gas samples from the same vessel or from two different vessels?" Making this decision correctly is a vetting process.

Initial evidence suggests the two samples came from different vessels. All of the measured venoarterial differences are in the "correct" direction (pH higher in the vein, PCO_2 lower in the vein, and PO_2 higher in the vein).

Data published by Yeomans, Hauth, Gilstrap, and Strickland, (11) based on "uncomplicated term vaginal deliveries," is a good data set with which to establish a normal range of pH and PCO_2 differences in cord gas analyses. As pH is the most reproducible of the measured parameters, it is taken as the primary determinant, and PCO_2 is used as the backup determinant. Using this data, assuming the differences between umbilical venous and arterial pH and PCO_2 have normal distributions, the 95th percentile range of differences for pH is from 0.04 to 0.10, and the 95th percentile range of differences for PCO_2 is from 4 to 18 mmHg, (3,4) (see Table 1 below). This suggests that when the pH difference is less than 0.04, the samples are probably from the same vessel. When the pH difference is borderline, i.e., 0.03, before concluding the umbilical venous and arterial samples came from the same vessel, check the PCO_2 difference. If the PCO_2 difference is less than 4 mmol/L, it is safe to conclude that the samples came from the same vessel.

In this case, the pH is borderline, 0.03. However, the PCO_2 difference is 5 mmHg, towards the lower end of the normal range, but normal nonetheless. Therefore, one should conclude that these samples came from different vessels, i.e., an umbilical vein and an umbilical artery. White et al.(12) and Westgate et al. (13) have suggested similar cutoff criteria for establishing samples from the same vessel.

Apgar scores were quite normal, further suggesting that cord blood gas samples would be normal. All of these findings lead to the conclusion that different vessels were sampled.

Umbilical Cord Venoarterial pH and Pco_2 Differences

	pH			Pco_2 (mmHg) *(kPa)*		
	Vein	**Artery**	**Delta***	**Vein**	**Artery**	**Delta***
	7.35	7.28	0.07	38 *5.07*	49 *6.53*	11 *1.46*
SD	0.05	0.05	0.0156	5.6 *0.75*	8.4 *1.12*	3.54 *0.47*
± 2 SD Range			0.039-0.101 (~0.04-0.10)			3.9-18.1 *0.52-2.41*
Borderline low delta*			0.03			

Table 1
Derived (3,4) in part from data published by Yeomans ER, Hauth JC, Gilstrap LC III, Strickland DM. Umbilical cord pH, PCO_2, and bicarbonate following uncomplicated term vaginal deliveries (146 infants). Am J Obstet Gynecol 1985;151:798-800.(11)
**Delta (the difference between umbilical venous and arterial values)*

For a discussion of widened umbilical cord venoarterial pH and PCO_2 differences, please see up-coming sections on cord occlusion with terminal fetal bradycardia and cases of fetal circulatory failure.

Key Points

- The normal range of pH differences between umbilical cord venous (higher) and arterial (lower) blood samples is 0.04 to 0.10. Larger differences may be seen under certain conditions.

- The normal range of PCO2 differences between umbilical cord venous (lower) and arterial (higher) blood samples is approximately 4 to 18 mmHg (0.52 to 2.41 kPa).
- A pH difference between umbilical cord venous and arterial samples of less than 0.03 signifies that both samples came from either an artery or a vein.
- A pH difference of 0.03 should be considered borderline. If, in addition, the umbilical venoarterial PCO2 difference is less than 4 mmHg, both samples should be considered to have come from either an artery or a vein.
- As the umbilical vein is much easier to sample than the artery when one concludes that both samples came from the same vessel, more likely it is the vein.

Case 6: Mislabeled Samples

The mother was a 19-year-old, gravida 1, para 0, aborta 0, with an intrauterine pregnancy at 38 3/7 weeks. Membranes had ruptured spontaneously with egress of clear fluid. She was in labor at the time of admission. The amniotic fluid was clear at the time of admission. The FHR showed intermittent variable decelerations that became more severe over time. After three hours, the mother was completely dilated, completely effaced, with the vertex at +2 station. The mother pushed for 90 minutes and was taken to the delivery room. Amniotic fluid was now lightly stained with meconium. The infant delivered 15 minutes later with Apgar scores of 6 and 8 at one and five minutes, respectively.

Cord blood gas results were as follows:

	Umbilical Vein	Umbilical Artery
pH	7.25	7.29
Pco_2 (mmHg) *(kPa)*	65 *8.67*	55 *7.33*
Po_2 (mmHg) *(kPa)*	14 *1.87*	21 *2.80*
HCO_3(mmol/L)	28	26
BD (mmol/L)	1	1

Interpretation

The venous pH and base deficit are normal, while the PCO_2 is mildly elevated, and the PO_2 depressed. The arterial sample is entirely within normal limits. However, the relationships between the "venous" and "arterial" blood gas samples, except for the base deficits, which are the same, are physiologically impossible. The first three "rules" of the relationship between pH, PCO_2, and PO_2 have been broken. The umbilical venous pH is not higher, the PCO_2 is not lower, and the PO_2 is not higher than the umbilical artery pH, PCO_2, and PO_2, respectively. Therefore, the results have been mislabeled. The correct labeling is as follows:

	Umbilical Vein	Umbilical Artery
pH	7.29	7.25
Pco_2 (mmHg) *(kPa)*	55 *7.33*	65 *8.67*
Po_2 (mmHg) *(kPa)*	21 *2.80*	14 *1.87*
HCO_3(mmol/L)	26	28
BD (mmol/L)	1	1

Now, one can see that the venous values are all normal, except for a mildly elevated PCO_2. The arterial sample results are all entirely normal.

"The base deficits in the umbilical venous and arterial samples are usually approximately equal, but if one base deficit is significantly worse than the other, it must be the arterial sample."

Key Points

- The umbilical venous blood gas always has a higher pH, a lower PCO_2 and a higher PO_2 than the umbilical arterial blood gas.
- The base deficits in the umbilical venous and arterial samples are usually approximately equal, but if one base deficit is significantly worse than the other, it must be the arterial sample.
- When the data reported are in the opposite (non-physiological) direction, suspect that the samples have been mislabeled.

Case 7: pH Alone versus Complete Blood Gas Analysis

The mother was a 35-year-old, gravida 4, para 1, aborta 2, with an intrauterine pregnancy at 34 weeks' gestation by poor dates. (14) Two years prior, the mother delivered an infant with intrauterine growth restriction. She was seen for the first time during this pregnancy when she came to the hospital with uterine contractions occurring every five minutes. The fundal height was 27 cm. The cervix was long and closed. Ultrasound examination revealed an infant with an estimated fetal weight of 960 grams, a grade III placenta, and markedly decreased amniotic fluid volume. No fetal breathing or body movements were noted. The FHR monitor revealed moderate recurrent late decelerations. The mother was taken for an urgent primary cesarean section. A male infant was

delivered with Apgar scores of 1, 5, and 7 at one, five, and 10 minutes, respectively. The birth weight was 920 g.

Cord blood gas results were as follows:

	Umbilical Vein or Artery
pH	7.22
Pco_2 (mmHg) *(kPa)*	Not Available
Po_2 (mmHg) *(kPa)*	Not Available
HCO_3^- (mmol/L)	Not Available
BD (mmol/L)	Not Available

Interpretation

The information provided is inadequate. A pH of 7.22 is low if from an umbilical vein and normal if from an umbilical artery. When a single sample is drawn from an umbilical cord, without instruction as to the vessel from which it is to be obtained, the sample is frequently venous, as the vein is much larger and easier to sample. Even when the goal is to sample the umbilical artery, some specimens may still come from the umbilical vein. In this case, without paired samples, there is no reliable way to know which vessel was sampled.

As stated above, if the sample is from the umbilical vein, the pH is slightly low. Is the pH low on a respiratory basis, on a metabolic basis, or a combination of both? Without a PCO_2, a base deficit cannot be calculated.

Cord occlusion with terminal bradycardia may result in a venous cord sample that is substantially better than its arterial counterpart. Was that the situation in this case? We do know that the FHR decelerations were described as "late" in configuration. Variable decelerations, suggestive of cord compression, were not reported. This suggests uteroplacental insufficiency rather than cord compression. Therefore, umbilical venous and arterial derangements should be similar. Additionally, this infant was extremely small for dates (probably asymmetric) with associated decreased amniotic fluid volume, conditions that frequently result from nutritional and respiratory uteroplacental insufficiency. (15) The decreased amniotic fluid volume further predisposes to cord compression (16) and prolonged decelerations. (17)

"Cord occlusion with terminal bradycardia may result in a venous cord sample that is substantially better than its arterial counterpart. Was that the situation in this case?"

Measuring only the pH leaves so many unanswered questions that the information is of very limited value. In the infant described above, the clinical presentation at least suggests the infant may have been more acidotic than reported. To assist in management, it would be appropriate to obtain a blood gas directly from the infant soon after transfer to the neonatal special care unit.

When umbilical cord blood is analyzed for pH, both PCO_2 and PO_2 should be measured as well, and bicarbonate and base deficit calculated from these results. This permits a much more meaningful analysis. Additionally, analyzing both umbilical venous and umbilical arterial blood provides the best basis for correct interpretation.

Key Points

- When only a single pH measurement is obtained from either an umbilical vein or artery sample, one cannot determine:
  - Whether the sample is from the vein or artery, or
  - Whether any acidosis present is respiratory, metabolic or mixed.

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