ORIGINAL RESEARCH

Evaluating Practice Consistency: Complying with the Directive to Obtain Umbilical Cord Arterial and Venous Blood Gasses, and Hemoglobin Values, at High-risk Deliveries

Sarah M Tweddell[1], Timothy M Bahr[2], Robin K Ohls[1], Robert D Christensen[1,2]

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Abstract

Introduction: Using Intermountain Health multihospital data, we quantified compliance with the American College of Obstetricians and Gynecologists directive to obtain umbilical cord arterial and venous blood gasses at high-risk deliveries. We also quantified compliance with our local directive to obtain hemoglobin with the cord gasses as an early screen for anemia.

Methods: Retrospective 24-month analysis of Intermountain Health deliveries.

Results: One-thousand-fifty births had "placental abruption" mentioned in the peripartum notes. These constituted our high-risk delivery study cohort. Of these, 726 (69%) had both a cord arterial and venous sample reported; 707 (67%) also had hemoglobin reported. In 86 (8%) only one (arterial or venous) was reported, and 293 (23%) had neither gasses nor hemoglobin. One-hundred-seven of the 726 had acidosis (cord arterial pH <7.13) and 619 did not (pH ≥7.13). Among those with acidosis, 82 had abruption confirmed after birth; in 25 abruption was not confirmed. Paired umbilical arterial vs venous hemoglobin levels revealed the novel observation that umbilical venous hemoglobin is slightly lower than arterial ($p < 0.0001$), perhaps due to maternal-to-fetal acellular fluid transfer. Among the 707 that had cord hemoglobin reported, fetal/neonatal anemia was diagnosed in 83 (12%) (defined as hemoglobin below the fifth percentile lower reference interval for gestational age).

Conclusions: We see an opportunity to improve compliance with the directives to obtain cord arterial and venous blood gas and hemoglobin at high-risk births. Doing so will allow rapid evaluation of about 30% more high-risk infants for the presence of acidosis and anemia at birth.

Keywords: Abruption, Acidosis, Artery vs vein, Hemoglobin, High-risk delivery, Umbilical.

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Introduction

In 2006, the American College of Obstetricians and Gynecologists published a Committee Opinion recommending that umbilical cord arterial and venous blood gas determinations should both be obtained at high-risk deliveries.[1] In addition to that recommendation, at Intermountain Health we request that a hemoglobin measurement be obtained with every umbilical cord gas, as a means of rapidly identifying anemia at birth, among these high-risk neonates.[2–4]

We were uncertain how frequently both an umbilical arterial and a venous blood gas, each with a hemoglobin level, are successfully being drawn and reported at our high-risk deliveries. In actual practice, the implementation of recommendations is virtually always incomplete, because barriers to full implementation exist. Steps toward more complete implementation of practice guidelines include quantifying compliance, identifying the barriers to full compliance, and working specifically to diminish or eliminate those barriers.

To assess our degree of compliance with the umbilical cord blood recommendations at high-risk births, and to begin the process of assessing implementation barriers, we performed a retrospective analysis in our multihospital system during the past 2 years. To reduce confounding variables and provide more uniformity and focus, we analyzed all deliveries where placental abruption was listed in the peripartum medical record.

Methods

Our study was a retrospective records analysis of neonates in the Legacy Intermountain Health databases. Intermountain Health is a not-for-profit organization that owns and manages hospitals in the Intermountain West of the USA. The Institutional Review Board (IRB) of Intermountain Health reviewed this proposal and approved it as exempt from the need for individual informed consent The diagnosis of placental abruption was initially screened from electronic data marts; Case Mix (the billing, coding, and financial data mart used by Intermountain Health), the extended

[1]Division of Neonatology, Department of Pediatrics, University of Utah, Salt Lake City, Utah, United States of America

[2]Division of Neonatology, Department of Pediatrics, University of Utah; Obstetric and Neonatal Operations, Intermountain Health, Salt Lake City, Utah, United States of America

Corresponding Author: Sarah Marie Tweddell, Division of Neonatology, Department of Pediatrics, University of Utah, Salt Lake City, Utah, United States of America, Phone: +1 8015817052, e-mail: Sarah.tweddell@hsc.utah.edu

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Table 1: Umbilical cord arterial and venous blood gas determinations and hemoglobin levels from $n = 1,050$ births where placental abruption was suspected before birth. Success in obtaining these laboratory tests is compared between the group where abruption was not confirmed at birth ($n = 372$) vs was confirmed at birth ($n = 678$)

Umbilical cord blood gas and Hgb measurements (n and % of total)	*Neonates where abruption was suspected, but not confirmed at birth (n = 372)*	*Neonates born after confirmed placental abruption (n = 678)*	*p-value*
Both arterial and venous cord gas	226 (60.8%)	500 (73.7%)	<0.001
Arterial gas only	13 (3.5%)	19 (2.8%)	
Venous gas only	12 (3.2%)	42 (6.2%)	
Neither	121 (32.5%)	172 (17.3%)	
Both arterial and venous Hgb	222 (59.6%)	485 (71.5%)	<0.001
Arterial Hgb only	8 (2.2%)	19 (2.8%)	
Venous Hgb only	10 (2.7%)	43 (6.3%)	
Neither	132 (35.5%)	131 (19.3%)	

Hgb, blood hemoglobin concentration

Vermont-Oxford database (EVOX), Storkbytes (the labor and delivery database), Fetal Link (a replacement for Storkbytes), provider problem lists, and International Classification of Diseases, Tenth Revision (ICD-10) coding.

The electronic medical record of every delivery that was identified by our screening ascertainment methods was individually reviewed by a member of the research team, not relying on coded information or on data tables. We did this to verify whether a diagnosis of placental abruption was confirmed after birth, and to evaluate each arterial and venous umbilical cord gas pair according to the criteria of Pomerance.[5] We judged the arterial and venous samples were mislabeled (switched) if the sample labeled "arterial" had a higher pH, a lower PCO_2, and a higher PO_2 than did the paired sample labeled "venous."

Neonates were included as having been born after a placental abruption if the obstetrician documented abruption in their procedure note, or if the pathologist confirmed abruption in their report. We attempted to characterize the size of each confirmed abruption using whatever descriptive metric we found in the medical record.

The dataset was collected and managed using an Intermountain Healthcare Research Electronic Data Capture (REDCap) electronic data capture tool; REDCap is a secure cloud-based application designed to support data capture and provide an intuitive interface for validated data entry, audit trails for tracking data manipulation and export procedures, automated export procedures for seamless data downloads to common statistical packages, and procedures for importing data from external sources. Summary statistics (means, counts, and proportions) were the primary quantitative tools used for analysis. Differences in continuous variables by group were assessed using one-way analysis of variance (ANOVA). Differences in categorical variables were assessed using either Chi-square tests or Fisher's exact test. Data management and statistical analysis were done in the R language and environment for statistical computing (R Foundation).

Results

Between 1 July 2020 and 30 June 2022, a total of 55,111 live births were recorded in our healthcare system. One-thousand-fifty of these (2%) had placental abruption mentioned in the peripartum medical record and identified by our initial ascertainment screen. Of the 1,050 live births, 678 (65%) had placental abruption subsequently confirmed at delivery, by the obstetrician or the pathologist, while in 372 (35%) an abruption was not found.

Of the 1,050 high-risk births that constituted our study cohort, both umbilical cord arterial and venous samples were reported from 726 (69%); 706 of these (67%) also had hemoglobin reported. In 86 (8%), only one sample (cord arterial or venous) was obtained, and in 293 (23%) no cord gas or hemoglobin value was reported. We found 25 paired samples that we judged to have had "switched labels," according to the criteria of Pomerance.[5] We recorded the corrected values accordingly. We were unable to determine what proportion of the umbilical cord blood tests were drawn from a double-clamped segment of the umbilical cord vs drawn from a single-clamped cord that remained attached to the placenta.[6] We were also unable to determine the time intervals between birth and drawing the sample, and between drawing the sample and running the test, including which of the specimens were transported on ice.[7]

As shown in Table 1, those where a placental abruption was confirmed were more likely to have both an arterial and a venous blood gas reported ($p < 0.001$). Those with a confirmed abruption were far less likely to have neither reported. The same occurred with cord blood hemoglobin reporting; namely, those with a confirmed abruption were more likely to have both arterial and venous hemoglobin values reported ($p < 0.001$) and were far less likely to have neither reported.

Of the 726 high-risk births where both an arterial and a venous cord blood gas value was reported, 107 had acidosis at birth, defined as a cord arterial pH <7.13 (using the definition of Johnson and Richards,[8] Table 2A) Of the 107 with acidosis, 82 had a placental abruption confirmed after birth and 25 had no evidence of an abruption. No differences in blood gasses were apparent between the group of acidotic neonates who had an abruption vs those who did not. Thus, among those with acidosis at birth, we were unable to distinguish cases of confirmed abruption based on blood gas values.

Six-hundred-nineteen of the 726 high-risk births did not have acidosis at birth (cord arterial pH ≥7.13). Four-hundred-eighteen of these had placental abruption confirmed after birth and 201 had no evidence of an abruption (Table 2B). Those with confirmed abruption were more likely to have a small difference (<0.15 pH units) between their venous and arterial pHs (suggesting poor placental function in correcting fetal acidosis, that is, their venous and arterial pHs were nearly the same)[5] (92% with abruption had this small difference vs 86% in those who did not have abruption,

Tables 2A and B: Umbilical cord venous and arterial pHs in 726 high-risk births. Table 2A includes only those who had acidosis (defined as a cord arterial pH <7.13).[8] Table 2B includes only those who did not have acidosis (defined as a cord arterial pH ≥7.13)[8]

(A) Acidosis (cord arterial pH <7.13) was present at 107 births

Venous and arterial pH	*Neonates where abruption was suspected by screening but was not confirmed at birth (n = 25*)*	*Neonates born after confirmed placental abruption (n = 82*)*	*p-value*
Difference (venous minus arterial, mean ± SD) in pH units	0.12 ± 0.11	0.11 ± 0.08	0.846
Percent with a difference of <0.15 pH units	17 (68%)	58 (71%)	0.991
Percent with a difference of ≥0.15 pH units	8 (32%)	24 (29%)	

*These analyses only include neonates for whom both a venous and arterial pH was available. SD, standard deviation

(B) Acidosis was not present (cord arterial pH ≥7.13) at 619 births

Venous and arterial pH	*Neonates where abruption was suspected by screening but was not confirmed at birth (n = 201*)*	*Neonates born after confirmed placental abruption (n = 418*)*	*p-value*
Difference (venous minus arterial, mean ± SD) in pH units	0.08 ± 0.05	0.07 ± 0.06	0.033
Percent with a difference of <0.15 pH units	173 (86%)	383 (92%)	0.046
Percent with a difference of ≥0.15 pH units	28 (14%)	35 (8%)	

*These analyses only include neonates for whom both a venous and arterial pH was available

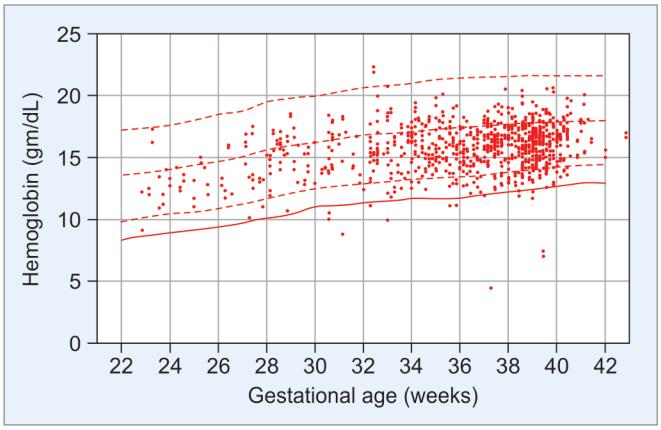

Fig. 1: Neonates were born when "placental abruption" was recorded in the perinatal medical record and had both a venous and an arterial umbilical cord blood gas, and hemoglobin values, reported. The lower dashed line indicates the fifth percentile lower reference interval (below which anemia is diagnosed) and the dark line indicates the first percentile lower reference interval (below which severe anemia is diagnosed).[3,9]

where presumably the placenta was functioning somewhat better ($p = 0.046$). This very small difference between venous and arterial pH was more common in those who did not have acidosis (Table 2B, 92%) than those who did have acidosis (Table 2A, 71%, $p < 0.001$). In 275 of the 500 confirmed abruption cases (55%) we found no indication of the abruption size, moreover the recorded abruption sizes were inconsistent and vague, making stratification of pH values according to abruption size impossible.[10]

Including a hemoglobin level with the umbilical cord blood gas proved to be a meaningful addition. As shown in Figure 1, among the 707 that had a cord hemoglobin reported, fetal/neonatal anemia was diagnosed in 83 (12%) (defined as a hemoglobin below the fifth percentile lower reference interval for gestational age), and severe anemia (defined as below the first percentile) was diagnosed in 16 (2%).[3] Of those with a confirmed abruption, 9% (63/678) had anemia at birth. Of those who did not have an abruption, 6% had anemia at birth ($p = 0.049$). In paired analyses, the venous hemoglobin level was lower (0.2 ± 0.8 gm/dL; mean ± IQR) than the arterial hemoglobin level ($p < 0.001$). The magnitude of arterial/venous hemoglobin difference did not correlate with the presence or absence of abruption or with the likelihood or severity of fetal/neonatal anemia.

Discussion

The American College of Obstetricians and Gynecologists and the American Academy of Pediatrics both recommend performing umbilical artery and venous blood gas determinations at deliveries where a fetal metabolic abnormality is suspected.[1,7] High-risk deliveries include conditions that are associated with fetal/neonatal anemia; thus, we recommend obtaining a hemoglobin value along with each arterial and venous cord blood gas as an early screen for anemia.[2,3,9] In the present study, we determined how often our delivery personnel successfully complied with these directives. We found that in 1,050 high-risk cases, blood gas was obtained from both umbilical vessels in 69% of births, and hemoglobin was obtained with the blood gas in 67%. We interpret these percentages as unsatisfactory because we are missing these important test results in about 30% of our high-risk deliveries, thus we are delaying a possible diagnosis of acidosis, as well as anemia, waiting on umbilical line placement and drawing of blood gasses and complete blood count (CBC) results.

We previously described that severe anemia at birth (hemoglobin measured within the first 6 hours after birth below the first percentile lower reference interval) was recognized and documented by caregivers in only 45% of those cases where severe anemia at birth actually occurred.[3] Obtaining a hemoglobin measurement along with umbilical cord gasses can identify anemia at birth. In our present analysis, we see much room for

improvement. In a large hospital system compliance with practice guidelines can be poor due to implementation barriers. At this point we are uncertain what these barriers are. However, surely skill in drawing these samples varies with training and experience.

In our present study, neonates who had acidosis at birth (arterial pH <7.13) did not have features on their arterial and venous blood gas that would differentiate those who had a placental abruption from those who did not have abruption. However, in neonates who did not have severe acidosis at birth (pH ≥7.13), the venoarterial pH difference was smaller in the group with confirmed placental abruption than in those who did not have abruption; namely, with abruption the arterial and venous pHs were nearly the same, indicating the abrupted placenta was failing to correct fetal acidosis. This phenomenon was originally reported by Johnson and Richards in 1997.[8] We also found that the umbilical cord venous hemoglobin was slightly lower than the umbilical cord arterial hemoglobin. We speculate that since maternal extracellular water is the source of fetal water, trace amounts of water must be transferred from mother to fetus through the placenta into the umbilical vein; thus, the hemoglobin value in the umbilical vein is typically very slightly lower (diluted) compared with that in the umbilical arteries.

We recognize limitations in our study. First, this was a retrospective analysis, relying on manual chart reviews that were only as accurate as was the reporting of those doing the patient charting. Also, we relied on the obstetrician or pathologist's report to document the abruption, but we know that estimation of the abruption size can be subjective. Another limitation includes a lack of accuracy in drawing and labeling cord blood samples. We found 25 paired samples where we judged the arterial and venous labels must have been inadvertently switched.[5] Pomerance notes several other potential errors in cord blood collection. For example, the two samples can be drawn by unknowingly sticking to the same vessel twice. This source of error is difficult to estimate or eliminate. A rare error is due to mixed venous and arterial blood, by sampling through a needle that traverses the artery and then slips into the vein next to it. We have no way of knowing how common this was in our dataset. Finally, we did not have access to cord blood after every high-risk delivery. We do not know why cord blood was not collected at all 1,050 deliveries, and whether their exclusion results in biases in our analysis. Moreover, we are uncertain what barriers exist to full implementation of the directive to obtain both arterial and venous cord gasses and hemoglobin at high-risk deliveries.[9]

In conclusion, we collected arterial and venous cord blood gasses, and hemoglobin, as our guidelines request, from about 70% of a high-risk delivery cohort. Thus, we see an opportunity to improve. Improvement will allow us to rapidly identify additional neonates with acidosis and also those with anemia, thereby generating timely, relevant, and sometimes critical information. We hope now that we have identified this opportunity, we can improve education and training of those charged with drawing these samples, thereby making this data rapidly available to another 30% of our high-risk deliveries.

Orcid

Timothy M Bahr https://orcid.org/0000-0002-7946-0290
Robert D Christensen https://orcid.org/0000-0001-5872-582X

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