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Can Fetal Umbilical Venous Blood be a Reliable Source for Admission Complete Blood Count and Culture in NICU Patients?

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Abstract

Background: Minimizing initial neonatal blood draws and their associated pain are important. The placenta has ample fetal blood that is otherwise discarded; obtaining admission laboratory studies from the fetal umbilical venous blood (FUVB) may provide a suitable alternative.

Objective: We hypothesized that obtaining an aerobic bacterial blood culture (BCX) and a complete blood count with manual differential (CBC/diff) from FUVB is feasible & yields comparable results to those obtained directly from the neonate.

Study Design: BCX and CBC/diff were attempted on paired samples from FUVB (in the delivery room) and neonatal blood (shortly after NICU admission) of 110 patients. Paired *t*-test, Pearson's correlation coefficient (*R*) and multivariable linear regression were used for data analysis.

Results: Positive BCXs were found in 9 of 108 FUVB compared to 1 of 91 neonatal samples. Three out of 9 FUVB cultures were true pathogens including 2 *Escherichia (E.) coli* and 1 viridans group streptococcus (VGS); all with negative correspondent paired neonatal cultures. There was 1 positive neonatal BCX, *E. coli*, with a negative paired FUVB culture. Neonatal hemoglobin (HB), platelets (PLT), and white blood cells (WBC) all significantly ($p<0.0001$) correlated with paired FUVB samples ($R=0.50$, 0.49 and 0.84, respectively). HB, PLT and WBC were clinically comparable but statistically higher in neonatal blood (differences were 2.3 g/dL, 30k cells/mcl & 2.8k cells/mcl respectively, $p<0.007$ for all comparisons).

Conclusions: FUVB is suitable for obtaining CBC/diff. FUVB is an appropriate second source for BCX as it yields additional true pathogens. Our findings may support the presence of "culture negative sepsis" in some neonates.

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Conflict of interest

The authors declare no competing financial interests or any conflicts of interest in relation to the work described.

Keywords

placental venous blood; cord blood; blood count; blood culture; neonatal sepsis

INTRODUCTION

Approximately 550,000 infants are born preterm in the US (<37 weeks gestational age [GA]) with over 90,000 < 32 weeks who require prolonged hospitalization[1]. Currently, many infants admitted to the NICU undergo a complete blood count with differential (CBC/diff), and when indicated, an aerobic blood culture (BCX), in addition to other tests. Approximately 1.5–5 ml of blood is needed to complete admission tests. Using the example of an extremely low birthweight (ELBW) infant of 700 g (blood volume ~ 50 ml)[2], the initial phlebotomy losses represent 3–10% of its blood volume. Given increased risk for early onset sepsis (EOS) in preterms[3–4]; “rule out sepsis” is a common reason for NICU admission. Signs of EOS are subtle; early and accurate detection leads to better outcomes. Many factors influence the yield of BCXs[5], but the most important one is blood volume[6–7]. Furthermore, neonatal phlebotomy (venipuncture/arterial stick) is painful and difficult to perform[8]. Blood sampling via heel lance may be suitable for obtaining CBC but not for culturing; additionally, it’s more painful compared with venipuncture[9].

Therefore, it seems prudent to consider the placenta, an otherwise discarded tissue, with its abundant fetal blood as an alternative source for NICU admission laboratory testing. The practice is gaining momentum[10–13], but mostly through case-controlled studies[12] or before/after quality-improvement programs[13]. Limited studies used a paired-sampling prospective design that included BCX[14–16] or focused on ill neonates[17]. We designed this study to include all NICU patients with a particular focus on the yield of paired BCXs from FUVB and neonatal samples in addition to analyzing CBC/diff results.

METHODS

This is a single-center, paired-sampling, prospective study conducted at UCI Medical Center (Orange, CA). All infants born at our hospital and admitted to the NICU within 1 hour were eligible. The period of recruitment was April-1, 2014 to April-8, 2016. Our Institutional Review Board approved the study and informed consent was required. To calculate sample size, the study was powered to test the hypothesis that there were clinically significant differences in hemoglobin (HB), white blood cell (WBC) and platelets (PLT) counts when drawn from the FUVB. Like Carroll *et al*[17], we sought to reject this hypothesis, therefore demonstrating that FUVB is an acceptable alternative. Using an internal survey, the following differences were considered clinically significant: 3 g/dL(HB), 40k (PLT) and 3k (WBC). Based on recent literature[18], we considered normal ranges as: HB (12–20 g/dL), PLT (110–400k/mcl) and WBC (5–29k/mcl). With $\alpha<0.05$ and 90% power, a sample size of 13, 37 and 45, respectively are required. Given the risks of clotting, PLT clumping, and technical difficulties, we sought to enroll 100 patients.

NICU nurses and two fellows were trained to draw FUVB (from umbilical vein or its tributaries near insertion to the placenta) using the method detailed previously[19]. Single

K_2EDTA Microtainer® tube (CBC/diff) and single aerobic BACTEC FX BCX bottle (BD Biosciences, Franklin Lakes, NJ) were used. Upon placental delivery, the nurse used sterile gloves and cleansed the placenta 3 times (at the point of umbilical cord insertion) with betadine. Using a 5-ml syringe/18-gauge needle, the umbilical vein was accessed and 3–5 ml of blood (0.5 ml for CBC; the rest for BCX) was collected. The time of sampling and the volume of blood injected into BCX bottles was not recorded. FUVB sampling was generally completed within 20 minutes of birth. Neonatal admission BCX (if indicated) and CBC were obtained per standard of care. Neonatal BCX was drawn from an umbilical arterial/venous catheter at time of insertion (UAC/UVC), a peripheral artery (PA) or a peripheral vein (PV). Admission neonatal CBC was drawn from UAC, UVC, PA or via capillary sampling. Source of collection was recorded. Per our NICU protocol, laboratory studies are completed within one hour of admission, however, exact timing for neonatal sampling was not recorded. Time of receipt of all samples (FUVB and neonatal) by laboratory was recorded. Delayed cord clamping or umbilical cord milking (DCC/UCM) was done sporadically (depending on the preference of the clinical care provider) during the study. DCC/UCM was recorded as a categorical variable (YES/NO); the duration of DCC or the frequency of cord milking as not recorded. However, our practice at the time of the study recommended DCC for 45–60 seconds or UCM for 3 times. FUVB and neonatal CBC were analyzed on the same instrument: Beckman-Coulter UniCel® DxH 800 Analyzer with VCSn module (Beckman Coulter, Inc. Brea, CA). Differential WBC was confirmed manually as well as review of blood smear. With regard to hematological measurements, samples with fibrin strands seen in blood smear were excluded from WBC and PLT analysis[17]. Samples that were clotted, had PLT clumps or fibrin strands were labelled as “damaged”. For the purpose of statistical analysis of HB, sources were consolidated into umbilical (U = UAC or UVC), peripheral (P = PA or PV) or capillary (C). Similarly, PLT and WBC sources were consolidated into central (CENT = UAC, UVC, PA or PV) or capillary (CAP). The clinical care providers were blinded to the results from the FUVB.

Statistical Analysis

Pearson’s correlation test coefficient (R) was used to assess the correlation between results from FUVB and neonatal blood. Paired t-test was used to test whether the differences between neonatal and FUVB results were different. Independent sample t-test, Wilcoxon rank sum test, and Chi-square test were occasionally used, as appropriate, to test subgroup differences. Multivariable linear (MVL) regression model was used to assess the association between neonatal blood and FUVB measures, adjusting for other characteristics from infant, mother and blood samples. Final models were obtained by using backward variable selection based on minimizing Akaike’s information criterion (AIC). SAS version 9.4 (SAS Institute, Cary, NC) was used. Two-sided tests with $p < 0.05$ were considered statistically significant.

RESULTS

We enrolled 110 subjects (Figure 1). Table-1 shows maternal/infant demographics. Major demographics (such as BW and GA) were similar between enrolled and non-enrolled patients (data not shown). The median times for samples to be received by the laboratory were 24 minutes (IQR 15–42) for FUVB and 75 minutes (IQR 65–105) for neonatal

samples. Sources for neonatal BCX were UAC (n=14), UVC (n=16), PA (n=19) and PV (n=42). Sources for admission neonatal CBC were UAC (n=14), UVC (n=14), PA (n =14), PV (n=14) or via capillary sampling (n=40). The source was unknown in 3 samples. As shown in Figure 1, there were 28% "damaged" samples in FUVB versus 16% for neonatal samples. Time FUVB received by the laboratory was significantly different between "damaged" and "non-damaged" samples (median 21 vs 31 minutes, p=0.021).

BLOOD CULTURE

Positive BCXs were found in 9 of 107 FUVB samples and in 1 of 91 neonatal samples (8.4% and 1.1%, respectively). Microorganisms recovered from FUVB samples included *E.coli* (2), viridans group streptococci (VGS; 2), coagulase-negative staphylococci (3) and mixed organisms (2). Based on clinical course of infants, inflammatory markers (WBC, Immature-to-total WBC ratio and C-reactive protein), speed of bacteria growth, placental histology of chorioamnionitis/funisitis, and consensus among investigators, 3 of these cultures were considered real pathogens (Table-2, true positive rate of 3.3%) and the rest were contaminants. One neonatal BCX was positive for *E. coli*; its paired FUVB culture was negative. There were no contaminants among neonatal BCXs.

COMPLETE BLOOD COUNT

Hemoglobin(HB)—A significant correlation (Figure-2A) was demonstrated between FUVB and neonatal HB. Neonatal HB was higher than FUVB HB with a mean difference of 2.3 g/dL (Table-3). MVL regression (Table-4) showed DCC/UCM and capillary source to be associated with higher neonatal HB. There were 2 FUVB samples with hematocrit (HCT) <30%; their correspondent paired neonatal HCT were normal. None of FUVB samples had HCT >65%. As for neonatal samples, there were no cases with HCT <30% but 7 cases with HCT >65%; all except one were capillary specimens. No neonates needed treatment for polycythemia as their repeat venous HCT was normal. If FUVB HCT < 30% or >65% was defined as abnormal, 2 out of 81 FUVB samples would have required redrawing (2.7%). On the other hand, 7 of 81 (8.6%) neonatal samples required redrawing for confirmation.

Platelet Count (PLT)—A significant correlation (Figure-2B) between FUVB and neonatal PLT was documented. Additionally, neonatal PLT was higher compared to FUVB with a mean difference of 30k (Table-3). MVL regression (Table-4) found that Cesarean delivery, exposure to chorioamnionitis and capillary source were associated with lower neonatal PLT. There were 9 FUVB samples with PLT <50k, all except 2 had paired neonatal PLT >100k. On the other hand, no valid neonatal blood samples had PLT <50k (after excluding damaged samples). No samples (FUVB or neonatal) had PLT >420. If FUVB is relied upon exclusively to assess PLT and if a count <50k was defined as abnormal/needing redraw, 9 out of 72 valid FUVB samples would have required redrawing (12.5%).

WBC, Absolute Neutrophil Count (ANC) and Immature/Total WBC Ratio—A significant correlation (Figure-2C) was noted between FUVB and neonatal WBC. Neonatal WBC was 2.8k cell/mcl higher than FUVB WBC (Table-3). MVL regression (Table-4) revealed that exposure to clinical chorioamnionitis, congenital malformations, and lower GA were associated with higher neonatal WBC. Analysis of ANC showed similar findings to

WBC. FUVB WBC and ANC were significantly higher in patients treated with antibiotics (ANC 6550 vs 3240, p=0.006) or exposed to clinical chorioamnionitis (9449 vs 4717, p= 0.004) but not histological chorioamnionitis. With regard to immature/total WBC ratio, there was no correlation between neonatal and FUVB samples (data not shown). There was one patient with FUVB WBC of 46.1k with a paired neonatal WBC of 66.9k. Conversely, there were 4 infants with FUVB ANC <1000; all of them had paired neonatal ANC >1000. None of the infants with Leukocytosis (>35k) or neutropenia (<1000) had a positive BCX. If leukocytosis or neutropenia are indications to immediately repeat FUVB CBC, 6.9% of valid samples would have required redrawing.

DISCUSSION

Obtaining timely admission laboratory studies from NICU patients is necessary for optimal care. In this study of high-risk NICU patients, we have demonstrated that drawing FUVB was technically feasible. There were 28% “damaged” samples (mostly due to clotting); a rate that is comparable to neonatal sampling in this study and to that of published literature (16–30%)[20–21]. We believe that the frequency of “damaged” samples can be reduced by prompt collection of FUVB and transport to the laboratory.

To our knowledge, this is the first study to evaluate paired cultures from FUVB and neonatal blood in high-risk neonates including ELBW infants. We found true positive cultures in 3 FUVB samples (2 *E. coli*, 1 VGS; 3.3%) with negative cultures in the corresponding neonatal samples. All of these infants had predisposing risk factors for EOS, were clinically ill, had laboratory evidence suggestive of EOS, and with placental histology showing severe chorioamnionitis/funisitis. With negative neonatal BCX, some neonatologists may consider these infants affected by “culture negative sepsis”. The reason for their “negative” neonatal BCX may include small blood volume for culturing compounded by low-grade bacteremia as a result of intrapartum antibiotics use. *E. coli* is the most common pathogen associated with EOS in premature infants[4]; it’s very unlikely to be a contaminant in our patients. VGS is the 2nd most common gram-positive organism to cause EOS[4]; as seen in one of our patients, it has been associated with intra-amniotic infection (and neonatal EOS) in mothers with PROM/PPROM[29]. As for the one true positive culture in a neonatal sample (*E. coli*) with a negative paired FUVB culture; it belonged to a late-preterm infant born after artificial rupture of membranes for 24 h. It is possible that this newborn had low-grade bacteremia at birth (hence negative FUVB BCX) but continued bacterial multiplication resulted in a positive neonatal BCX 72 minutes later. We acknowledge that 6 other cultures from FUVB grew microorganisms that were contaminants. The etiology for this is not clear; we followed the same sterile/antiseptic technique for both FUVB and neonatal blood culturing, both procedures were done by the same NICU staff and we had zero contamination from neonatal samples. However, we did not practice drying the placental surface first before applying betadine; we speculate that the wet placental surface could have diluted the antiseptic solution rendering it less effective and resulting in a relatively high contamination rate.

Several studies[14–16, 30–31] examined the utility of cord/FUVB for detection of EOS using different techniques with a reported contamination rate ranging from 0%[14] to 12.5% [16]. Polin *et al.*[30] evaluated 200 cord samples (drawn from excised umbilical cord

segment) with only 29 paired infant samples and found 6 positive cultures; only one was declared a true pathogen (α-hemolytic streptococcus). Beeram *et al.*[15] evaluated 200 term and preterm (34.4 ± 4.4 weeks GA) infants at risk for EOS. They identified 2 positive BCX in cord samples, one of them was a pathogen (GBS) and the other was a contaminant; they also recovered 2 positive BCX from neonatal samples, one of them was a pathogen (*E. coli*) and other was a contaminant. More importantly and similar to our finding and that of Herson *et al.*[31], there was a discordance between true positive cultures in cord and neonatal blood, underscoring the importance of obtaining blood from both sources. Despite the contamination issue, cord/FUVB offers advantages as a second source for culturing as it represents a "kinder/gentler approach"[32], allows for larger blood volume and, as we and others have shown[15,31], identifies true pathogens not recovered from neonatal sampling. Our data provides some support to the presence of "culture negative sepsis", a problem that neonatologists face daily. If agreed that 4 neonates in our study had true EOS, a culture obtained from FUVB yields sensitivity (SN) of 75%, specificity (SP) of 94%, positive predictive value (PPV) of 33% and negative predictive value (NPV) of 99% for identifying EOS. On the other hand, the corresponding values for a neonatal BCX are SN 25%, SP 100%, PPV 100% and NPV 97%. Some may question if widespread use of FUVB for culturing, with its enhanced sensitivity to detect EOS, would increase utilization of antibiotics in NICUs. This issue may be viewed negatively in the era of antibiotic stewardship. We argue that identifying true EOS with positive culture and antibiotic sensitivities would lead to a focused narrow spectrum antibiotic utilization. Furthermore, identifying true EOS is likely to reduce frequent "serial" sepsis screening with CBC, C-reactive protein and other tests. Although contamination rate was higher with FUVB, we contend that it's not too difficult to separate true pathogens from contaminants based on clinical, bacteriological and other laboratory criteria (Table-2). Moreover, we believe contamination rate can be reduced with team training and optimizing the sampling method.

We demonstrated that neonatal admission HB correlated well but was higher than FUVB. These findings are in agreement with the published literature[12,15–17] and with a naturally expected increase in HB seen a few hours post-birth[18]. The increase could be due to intravascular concentration of blood received by placental transfusion and in part, due to evaporative fluid losses. As expected, the increase was more pronounced when neonatal blood was obtained from a capillary source[22–23] and with DCC/UCM[24–25]. Our study is different in that DCC/UCM was performed in about 30% of study infants, which may explain the more pronounced increase in HB we saw compared to Carroll *et al*[17]. We consider that FUVB measurement of HB/HCT to be more accurate than neonatal capillary measurement as it avoids a false diagnosis of polycythemia. This concept may seem counterintuitive in the new era of DCC where polycythemia is a concern, however, a recent meta-analysis of DCC found that the procedure increased peak hematocrit by only 2.7%[24]. We propose that capillary source sampling is the leading cause of false diagnosis of polycythemia; use of FUVB will avoid it in the majority of cases. Furthermore, these infants are closely monitored in the NICU and many will undergo a repeat CBC at 12–24 h, which makes missing true polycythemia unlikely.

We noted a good correlation and a marginal increase in admission neonatal PLT compared to FUVB, especially when the source of neonatal sampling is central. This small increase is in

contrast to what is reported by others[15–17] where Carroll *et al.* and Rotshenker-Olshinka *et al.* found no significant differences but Beeram *et al.* reported a drop of about 14k. The reason for the small increase in neonatal PLT seen in our study is not clear; we speculate it could be due to placental transfusion as well as evaporative fluid losses (making all blood component concentrated). Alternatively, the delay in obtaining FUVB samples may have resulted in falsely low PLT due to sub-microscopic clotting not detected by review of blood smear. We made every effort to control for this issue by excluding damaged samples from analysis. The association between capillary sampling and low PLT seen in the regression model is well established[23,26]. The link between cesarean delivery and PLT is not clear; it could be due to the fact that operative deliveries are more common in mothers with preeclampsia, which in turn predisposes to neonatal thrombocytopenia[27]. Clinical chorioamnionitis predisposes to EOS and thrombocytopenia is commonly associated with neonatal infections[28]. The need to re-draw for low PLT (12.5%) is comparable to that reported by Carroll *et al.* (~ 10%)[17].

Our finding that neonatal WBC correlates very well and is higher compared to paired FUVB is in agreement with other investigators[14–17]. WBC and ANC increase rapidly after birth reaching their peak at 6–12 h of life in term and older preterm infants and up to 36 h in ELBW infants < 28 weeks GA[18]. We speculate that the increase in admission neonatal WBC is due to this natural phenomenon (neonatal samples were received ~ 77 minutes after birth). Additionally, labor and delivery result in maternal physiological leukocytosis shortly after birth[29]; it is unclear if similar mechanisms are responsible for a rise in neonatal WBC/ANC. As expected, FUVB WBC and ANC were significantly higher in patients exposed to clinical chorioamnionitis and in those treated with antibiotics indicating their ability to “screen” patients at risk for EOS.

Strengths of our study include its pragmatic and prospective design with paired-sampling, a relatively large sample size and the inclusion of MVL regression analysis. Although a pragmatic design may create a heterogeneous group of subjects and be viewed as a weakness, we consider it as strength since it makes our findings relevant to the “real world” of neonatology practice. Our study is the first to include linear regression modeling to identify the impact of several factors on CBC indices. The impact of other variables including DCC/UCM, source of collection, mode of delivery and admitting diagnosis, may explain, in part, the weak correlation in CBC indices (especially HB and PLT, R <65) between FUVB and neonatal samples demonstrated in this and other studies[14–16]. Limitations include poor enrollment of patients, the presence of damaged samples, probable delay in obtaining FUVB and presence of contamination. We believe some of the limitations (sampling delay/damaged samples/contamination) could be minimized by refining the methodology (drying the placental surface before sampling) and with team training.

Conclusions

FUVB is an acceptable source for CBC/diff in all NICU admissions. HB, PLT, and WBC are generally lower when analyzed from FUVB but the differences are not clinically significant. FUVB is a useful addition to neonatal blood culturing in EOS as it yields additional true pathogens not recovered by standard methods. Utilization of FUVB for NICU admission

laboratory evaluation decreases iatrogenic blood loss and produce results more quickly. Furthermore, the procedure does not interfere with DCC/UCM; an additional measure that boosts neonatal blood volume and minimizes the impact of phlebotomy losses. Additional studies are needed, especially from high-risk NICU patients, to validate the findings of this study and decrease the BCX contamination issue reported in this and other studies.

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Box of Abbreviations

ANC	Absolute Neutrophil Count
BCX	Aerobic blood Culture
BW	Birth Weight
CBC	Complete Blood Count
DCC/UCM	Delayed Cord Clamping/Umbilical Cord Milking
ELBW	Extremely Low Birth Weight
EOS	Early-Onset Sepsis
FUVB	Fetal Umbilical Venous Blood
GA	Gestational Age
GBS	Group B streptococcus
HB	Hemoglobin
HCT	Hematocrit
MVL	Multivariable Linear Regression
NICU	Neonatal Intensive Care Unit
PA	Peripheral Artery
PLT	Platelet
PV	Peripheral Vein

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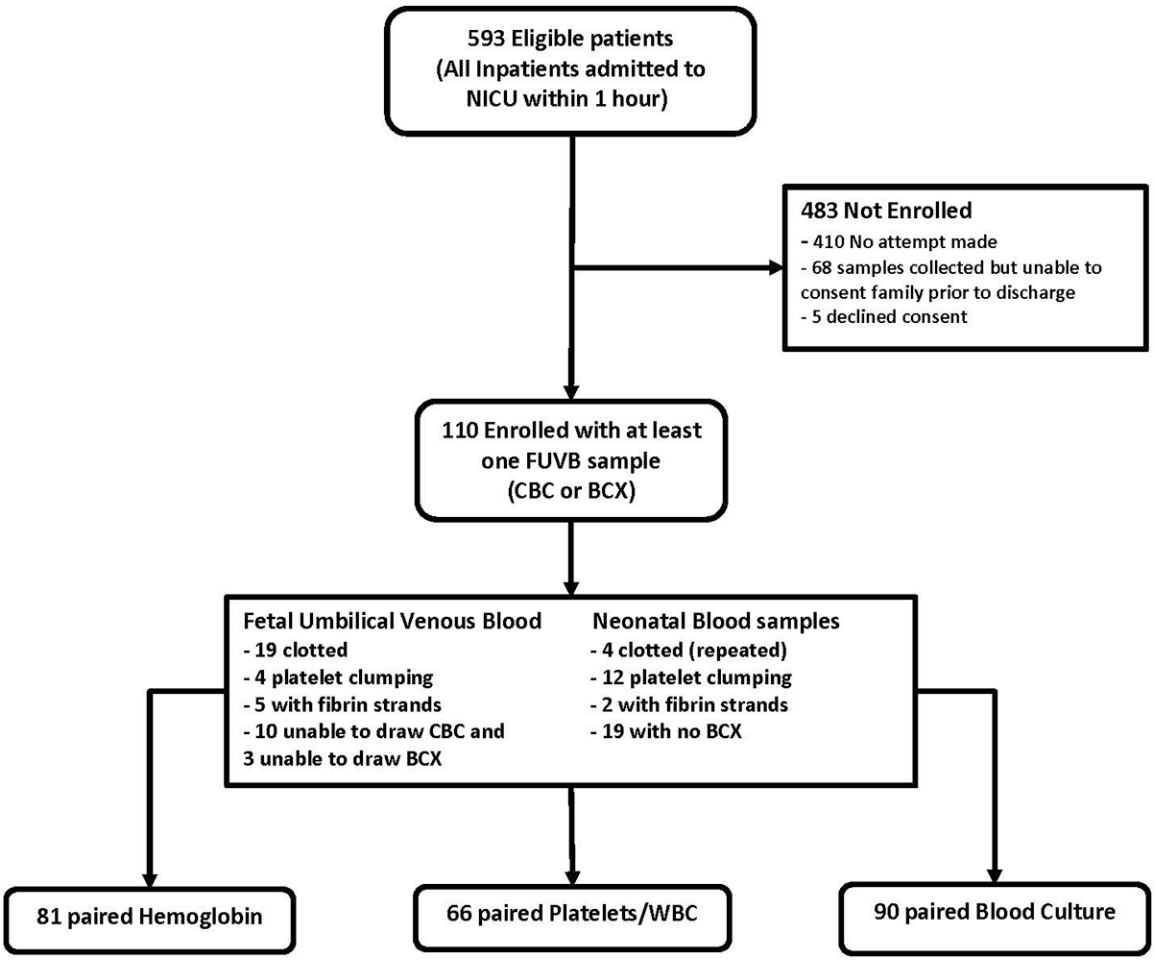

Figure 1.

Enrollment flow chart for the study population (110 NICU admissions). FUVB: Fetal umbilical venous blood. CBC: complete blood count. BCX: blood culture. WBC: white blood cells.

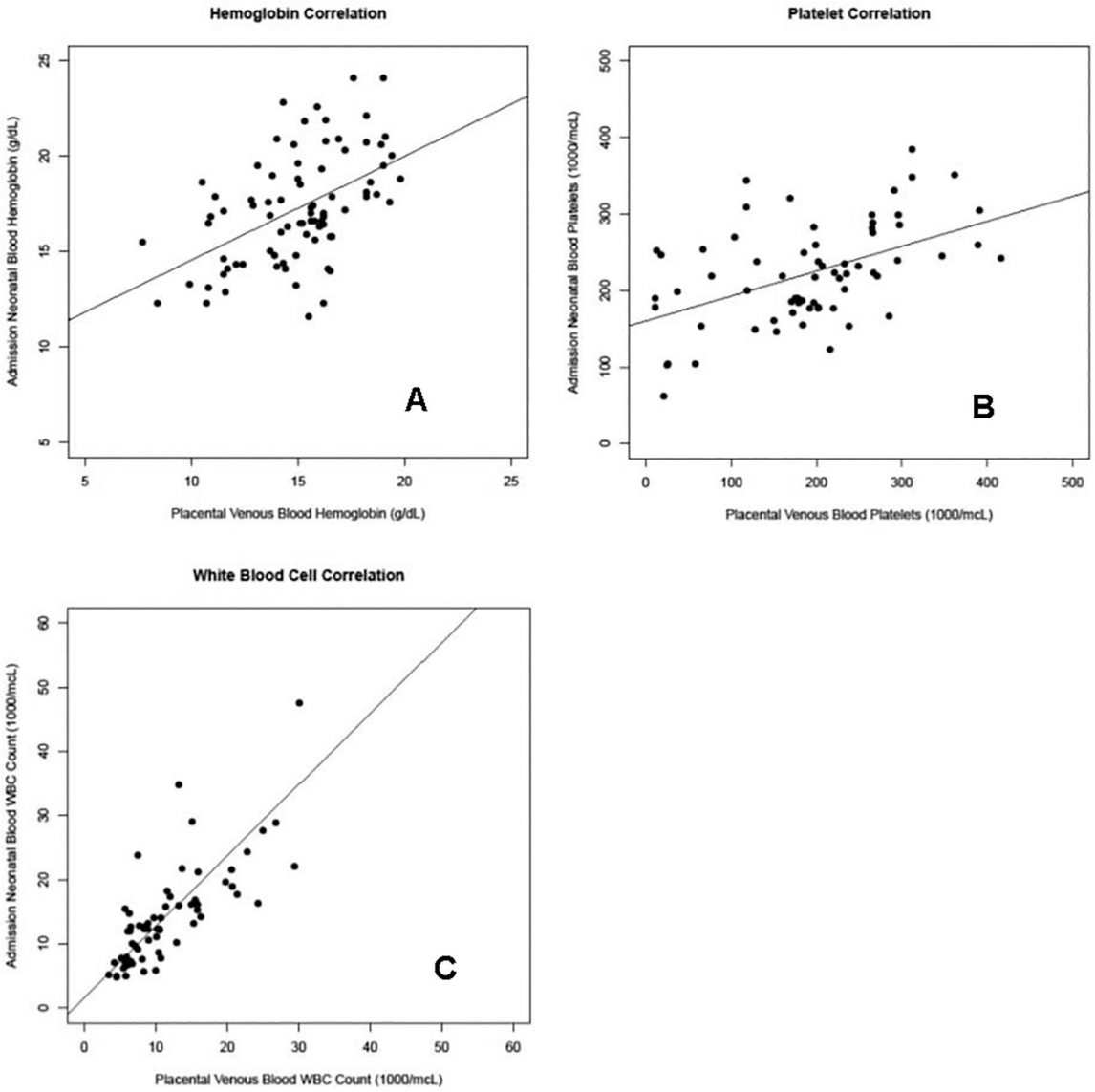

Figure 2.

Scatter plot of hemoglobin (A), platelets (B) and white blood cells (C) fetal umbilical venous blood and admission neonatal blood.

Table 1.

Maternal and infant demographics..

Birth weight, mean (SD), g (range)		**2079 (820)** (431–4250)
	VLBW Infants (<1500 g), (n)%	**(28) 25%**
	ELBW infants (<1000 g), (n)%	(9) 8%
GA, mean, (SD), weeks (range)		**33.5 (4)** (24–41)
	Preterm (<32 weeks),(n)%	**(39) 35%**
Apgar Score (median)	One minute (IQR)	7 (4–8)
	Five minutes(IQR)	9 (8–9)
Growth	(n)% SGA	(12) 11%
	(n)% LGA	(8) 7%
Gender [(n), % Female]		**(54) 49%**
Race/Ethnicity (n) %	Hispanic	**(65) 59%**
	White	(24) 22%
	Other	(21) 19%
Mode of delivery	(n)% Caesarean	**(66) 60%**
Clinical chorioamnionitis, (n)%		**(24) 22%**
Histological Chorioamnionitis, (n)%		**(29) 27%**
ROM>18 hours, (n)%		**(33) 30%**
GBS positive or unknown, (n)%		**(66) 60%**
Antibiotics Exposure [(n)%]	Any	(90) 82%
	≥ 7 days	**(25) 23%**
DCC/UCM, (n)%		**(32) 29%**
Maternal Diabetes, (n)%		**(20) 18%**
Multiple Gestations, (n)%		**(28) 25%**
Congenital Malformations, (n)%		**(13) 12%**

ROM: rupture of membranes; GBS: group B streptococcus; DCC/UCM: Delayed cord clamping/umbilical cord milking

Table 2:

Clinical and laboratory characteristics of infants with TRUE positive cultures.

BW (g)	GA (wks)	EOS Risk Factors	1st N-WBC/ITR	1st/2nd N-CRP	BCX From PVB	BCX from neonate	Growth Signal (hours)	Placental Histology	Comments
760	**25.6**	**CCA**	18.2/**0.32**	0.5/0.5	**Positive - E.coli**	Negative	**12.25**	**Severe chorio-amnionitis**	Infant developed unexplained respiratory distress with several apneas and metabolic acidosis 24 hours after stopping antibiotics.
3250	41.1	**CCA**	24.4/**0.45**	**1.7**/0.8	**Positive - E.coli**	Negative	**12.5**	**Severe chorio-amnionitis;Severe funistis**	Infant born via thick meconium. Noted to be limp and apneic at birth and needed mechanical ventilation with slow recovery.
2860	40.7	**CCA; membranes rupture x 25 hours**	21.7/**0.31**	**4.3/2.7**	**Positive - VGS**	Negative	**31**	**Severe chorio-amnionitis**; **Severe funistis**	Infant born via C-section for CAT II tracings with thick meconium. Developed respiratory distress and needed nasal CPAP x 24 h.
2600	**34**	**Membranes rupture x 24 hours**	8.6/**0.28**	**3.4/0.9**	Negative	**Positive - E.coli**	**14.8**	**Moderate chorio-amnionitis**; **moderate funistis**	Late preterm infant born via urgent C-section due to category II tracing after induction of

BW (g)	GA (wks)	EOS Risk Factors	1st N-WBC/ITR	1st/2nd N-CRP	BCX From PVB	BCX from neonate	Growth Signal (hours)	Placental Histology	Comments
									labor with artificial ROM x 24 hours. Developed respiratory distress and needed CPAP x 48 h.

BW: birthweight. GA: gestational age in weeks. EOS: early-onset sepsis. 1st N-WBC/ITR: first neonatal WBC / immature to total neutrophil ratio. 1st/2nd N-CRP: first (within 12–24 hours) and second (within 24–36 hours) neonatal C-reactive protein. BCX: blood culture. PVB: placental venous blood. CCA: clinical chorioamnionitis. CAT II: category 2 tracing on fetal heart rate monitoring. VGS: viridans group streptococci. Abnormal findings are in **bold**.

Table 3:

Differences and paired t-test as well as Pearson's correlation between test results from fetal umbilical venous blood (FUVB) and neonatal blood samples.

Outcome	Neonatal Mean (±SD)	FUVB Mean (± SD)	Differences* Mean (95%CI)	P-value (T-test)	Pearson's Correlation	P-value (Correlation)
HB	17.3 (± 2.88)	15 (±2.7)	2.3 (1.7, 2.9)	<0.0001	0.50	<0.0001
Plat	222 (±66)	192(±100)	30 (8.8, 52)	0.0066	0.49	<0.0001
WBC	14.9 (±10.1)	12.1(±7.7)	2.8 (1.5, 4.2)	0.0001	0.84	<0.0001

HB: Hemoglobin; WBC: White blood cells; SD: standard deviation; CI: confidence intervals.

*Difference is test measure from neonatal blood minus measure from PVB.

Table 4:

Multivariable linear regression for neonatal hemoglobin (HB), platelets and white blood cell count (WBC) with fetal umbilical venous blood (FUVB) results as main exposure covariate, adjusting for characteristic of neonatal blood sample and patients.

Outcome	Variable	Category	Estimate	StdErr	P-value	Adjusted R-squared
HB	DCC/UCM	Yes vs. No	1.59	0.58	0.0078	0.48
	Source of collection for neonatal samples	Capillary	2.65	0.72	0.0005	
		Peripheral	0.21	0.65	0.7439	
		Umbilical (Ref)	0.00			
Platelets	Mode of delivery	C-section	−43	13.9	0.003	0.50
		Vaginal (Ref)	0.00			
	Clinical Chorioamnionitis	Yes vs. No	−39	21.4	0.072	
	Source of collection for neonatal samples	Capillary	−55	15.3	0.0007	
		Central (Ref)	0.00			
WBC	Clinical Chorioamnionitis	Yes vs. No	5.25	2.39	0.033	0.72
	Congenital malformations	Yes vs. No	4.90	2.26	0.035	
	Gestational Age		−0.76	0.26	0.0048	

DCC/UCM: Delayed cord clamping/umbilical cord milking.