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Evaluation of Introduction of a Delayed Cord Clamping Protocol for Premature Infants in a High-Volume Maternity Center

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Abstract

OBJECTIVE—To evaluate adherence to a delayed cord clamping protocol for preterm births in the first two years after its introduction, perform a quality improvement assessment, and determine neonatal outcomes associated with protocol implementation and adherence.

METHODS—This is a retrospective cohort study of women delivering singleton neonates at 23–32 weeks of gestation in the 2 years prior to (preprotocol)-and 2 years after (postprotocol) introduction of a 30 second delayed cord clamping protocol at a large volume academic center. This policy was communicated to obstetric and pediatric health care providers and nurses and reinforced with intermittent educational reviews. Barriers to receiving delayed cord clamping were assessed using chi-square tests and multivariable logistic regression. Neonatal outcomes were then compared between all infants in the preprotocol period and all infants in the postprotocol period; and between all infants in the preprotocol period and infants receiving delayed cord clamping in the postprotocol period using multivariable linear and logistic regression analyses.

RESULTS—Of the 427 eligible neonates, 187 were born postprotocol. Of these, 53.5% (N=100) infants received delayed cord clamping according to the protocol. The rate of delayed cord clamping pre-protocol was 0%. Protocol uptake and frequency of delayed cord clamping increased over the 2 years after its introduction. In the postprotocol period, cesarean delivery was the only factor independently associated with failing to receive delayed cord clamping (aOR 0.49, 95% CI

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0.25–0.96). In comparison to the preprotocol period, those who received delayed cord clamping in the postprotocol period had significantly higher birth hematocrit (β 2.46, $p=0.007$) and fewer blood transfusions in the first week of life (aOR 0.49, 95% CI 0.25–0.96).

CONCLUSIONS—After introduction of an institutional delayed cord clamping protocol followed by continued health care provider education and quality feedback, the frequency of delayed cord clamping progressively increased. Compared to historical controls, performing delayed cord clamping in eligible preterm infants was associated with improved neonatal hematologic indices, demonstrating the effectiveness of delayed cord clamping in a large-volume maternity unit.

INTRODUCTION

Preterm birth and its associated complications account for significant neonatal morbidity and mortality,^{1,2} including an increased incidence of intraventricular hemorrhage, bronchopulmonary dysplasia, sepsis, necrotizing enterocolitis, and hemodynamic instability.^{3,4} The appropriate use of progesterone therapy to reduce the occurrence or recurrence of preterm birth, and corticosteroids and magnesium sulfate to reduce neonatal morbidity if preterm birth occurs are examples of prenatal interventions. However, delayed cord clamping is an intrapartum procedure which may also benefit the premature infant.

Delaying clamping of the umbilical cord in preterm neonates improves hemodynamic stability and immune function by increasing blood volume and oxygenation due to the additional iron, immunoglobulins, and stem cells delivered from the placenta.⁵ Multiple randomized control trials have demonstrated preterm infants who receive delayed cord clamping are less likely to require intubation in the delivery room, receive red blood cell transfusions in the first week of life, or develop intraventricular hemorrhage (IVH).⁶ Delayed cord clamping is also associated with decreased risk of hypothermia, necrotizing enterocolitis, sepsis, and need for blood pressure support.^{6,7} Additionally, this intervention has not been found to result in adverse consequences.^{8,9} Given this evidence, in December 2012, the American College of Obstetricians and Gynecologists (the College) recommended 30–60 seconds of delayed umbilical cord clamping in all premature infants when feasible¹⁰, and recently expanded these guidelines to include a recommendation for delayed cord clamping for all neonates.¹¹ These recommendations were further endorsed by the American Academy of Pediatrics in 2013.¹²

Despite the College's recommendation, the actual practice of delayed cord clamping has varied widely among obstetricians nationwide, even in settings where protocols have been attempted, and patient factors that influence health care provider adherence to delayed cord clamping remain poorly understood.^{10,13} Therefore our aim was to evaluate a delayed cord clamping protocol introduced in an institution with a large, diverse obstetric population. The study objectives were 1) to perform a quality improvement evaluation of adherence to the delayed cord clamping protocol and 2) to investigate neonatal outcomes associated with the implementation of delayed cord clamping.

MATERIALS AND METHODS

This is a retrospective cohort study of women delivering singleton neonates 23–32 weeks' gestational age in the 2 years prior to and 2 years following institution of a delayed cord clamping protocol at a large volume academic center. At this medical center, approximately 12,000 births occur per year, and deliveries are performed by both private and university-employed faculty, with residents typically involved in preterm deliveries. Health care provider types include maternal-fetal medicine physicians, obstetric physicians, and midwives. Delayed cord clamping was not routinely performed prior to introduction of this protocol.

This institution's 2013 delayed cord clamping protocol, based on a review of existing literature and College and American Association of Pediatrics recommendations, includes clamping the umbilical cord 30 seconds after delivery for preterm infants 23–32 weeks gestational age. For vaginal deliveries, proper technique includes wrapping the infant in a sterile towel and holding it below the level of the maternal introitus, while cesarean deliveries involve wrapping the infant in a sterile towel and placing it on the lower maternal abdomen or legs. A designated member of the delivery team tracks the time of the delay and ensures proper documentation and team communication. Neonatal resuscitation is initiated by the neonatal team immediately after clamping and cutting the umbilical cord. Exclusion criteria include multiple gestations, estimated gestational age < 32 week 0 days, general anesthesia, major fetal anomalies, or no intent to resuscitate. The procedure can also be terminated at any time at the discretion of the obstetrician or neonatologist for a newborn thought to have more immediate resuscitative needs. Planned cord blood banking or donation is not considered an indication to abstain from performing delayed cord clamping.¹⁴ Neonates eligible for DCC by this protocol constituted this study's analysis sample.

Beginning in July 2013, the delayed cord clamping policy was communicated to obstetric and pediatric providers and nurses, and reinforced through intermittent educational sessions on the benefits of delayed cord clamping for preterm neonates. Health care providers were strongly recommended to delay cord clamping in eligible neonates per this quality improvement initiative but were not mandated to do so. At this institution, all very preterm births are attended by resident physicians who are always supervised by attending obstetricians; all neonatal resuscitation teams include an attending neonatologist. Educational sessions were directed by a delayed cord clamping quality-improvement team composed of maternal-fetal medicine, nursing and neonatology personnel. At these sessions, audit and feedback with regard to protocol adherence was provided by one investigator (LY) along with NICU leadership. At periodic intervals (Figure 1), reeducation to residents, fellows, nurses, and attending physicians was provided via updates at dedicated nursing, resident, and fellow lectures, brief educational lectures at labor and delivery sign-out, departmental grand rounds, signage and flyers, email reminders, and in-person reminders at the time of deliveries. After 12 months of the delayed cord clamping protocol and data review (performed routinely as part of the quality improvement process), nurse-led initiation of the delayed cord clamping procedure was added to the protocol, such that neonatal and obstetric nursing remind the accoucher to perform delayed cord clamping immediately prior

to delivery, count the time aloud during the delay, and document the procedure occurrence in the maternal and neonatal electronic medical record. The electronic labor board is additionally utilized to remind teams about intent for delayed cord clamping.

This analysis includes the 2 years prior to (pre-protocol period: January 1, 2011, to June 30, 2013) and the 2 years after (post-protocol period: July 1, 2013 to June 30, 2015) the introduction of the delayed cord clamping protocol. Data were abstracted from the electronic medical record. First, eligible deliveries within the post-protocol period were assessed for the quality improvement aim of adherence to and completion of the protocol. After introduction of the protocol, the frequency with which eligible neonates received delayed cord clamping was calculated on a monthly basis and plotted on a run chart. Run charts can be used to demonstrate signals of improvement in a process and to examine if changes in a process lead to improvements over time, such as increase in health care provider adherence to the protocol. Each point graphically represents a percentage adherence to a given quality improvement measure. In this study, each data point represents the proportion of babies in a given month who received delayed cord clamping out of all who were eligible. Non-random patterns of improvement were analyzed using the median and standard run chart evaluation rules. The two run chart rules used for the study include a shift, a period in which six or more consecutive points all fall above or below the median, and a trend, a period in which five or more consecutive points all rise or fall.¹⁵ We then compared maternal and perinatal characteristics between eligible women who did and did not receive delayed cord clamping in the post-protocol period in order to identify factors independently associated with the likelihood of performance of the protocol.

To address the second aim, outcomes associated with implementation of delayed cord clamping, we assessed the association between delayed cord clamping and neonatal hemodynamic and hematologic outcomes in two manners. Maternal and neonatal characteristics in the pre-protocol and post-protocol cohorts were compared. To assess the overall impact of delayed cord clamping protocol introduction, we compared all neonates in the pre-protocol period (none of whom had received delayed cord clamping) with all neonates in the post-protocol period. To assess the impact of actual performance of delayed cord clamping, we performed a per-protocol analysis, comparing all neonates in the pre-protocol period to the subgroup of neonates in the post-protocol period who received delayed cord clamping per guidelines.

Neonatal outcome data included a number of post-delivery hemodynamic, procedural and laboratory outcomes such as initial temperature, birth hematocrit, red blood cell transfusions, length of mechanical ventilation, peak bilirubin, need for pharmacologic blood pressure support, bronchopulmonary dysplasia (BPD), necrotizing enterocolitis, late onset sepsis, grade III/IV intraventricular hemorrhage (IVH), and neonatal death. Need for pharmacologic blood pressure support was defined as any need for inotropic support in the neonate. BPD was defined as continued need for supplemental oxygen at 36 weeks corrected gestational. Necrotizing enterocolitis was defined as Bell's stage 2 with confirmation on abdominal radiography.¹⁶ Late-onset sepsis was defined as culture positive sepsis at least 3 days after delivery. Grade III/IV IVH was recorded based on the Papile et al criteria.¹⁷

This study was approved by the Institutional Review Board of Northwestern University. Maternal and neonatal characteristics and outcomes were compared using the Student *t* test or Mann-Whitney *U* test where applicable for continuous variables, and χ^2 or Fisher exact test where applicable for categorical variables. Multivariable logistic regression was used to identify factors associated with delayed cord clamping performance in the post-protocol period. For the assessment of neonatal outcomes, linear and logistic regression models were used to assess the independent association between a) cohort and neonatal outcomes and b) receipt of delayed cord clamping and neonatal outcomes. Multivariable models adjusted for demographic and clinical characteristics that were significant at $p < 0.1$ in bivariable analysis. All tests were two-tailed and $p < 0.05$ denoted significance. All statistical analyses were performed with SPSS Statistical software (Version 22; IBM Corp, Armonk, NY). The run chart was created using Microsoft Excel (Microsoft Corporation, Redmond, WA) and analyzed using standard run chart analytical techniques¹⁵ to apply probability-based rules for determining non-random changes in data.

RESULTS

A total of 427 neonates met inclusion criteria during the study period. Of these, 240 were delivered before and 187 were delivered after the introduction of the protocol. Of the 187 post-protocol patients, 53.5% (N=100) received delayed cord clamping, whereas 0% received delayed cord clamping prior to protocol introduction.

The run chart in Figure 1 illustrates monthly adherence rates to the delayed cord clamping protocol. The institutional goal was set at 80% after discussion among neonatal and obstetric providers. This chart demonstrates the significant improvement in delayed cord clamping compliance that occurred after initiation of the protocol in July 2013 as determined by standard run chart probability-based rules. First, a shift occurred from February 2014 to September 2014, demonstrating a non-random period of sustained improvement in protocol performance. Decreases in compliance were always followed by a rebound in adherence with reeducation. Second, two trends were observed: between July 2013 and November 2013 (protocol initiation) and again between January 2015 and June 2015 (after protocol reeducation). Both periods were evidence of significantly improving performance in distinct time periods. Such findings indicate that the improvement in delayed cord clamping adherence was not due to chance.

Next, we identified factors associated with adherence to the delayed cord clamping protocol in the post-protocol period. Maternal demographic and clinical characteristics were similar between women who did and did not receive delayed cord clamping (Table 1). The mean gestational age for neonates who received delayed cord clamping was not significantly different than the mean gestational age for those who did not in the post-protocol group (29.5 ± 2.0 weeks vs. 29.2 ± 2.8 weeks, $p=0.94$). However, on bivariable analysis, women who received delayed cord clamping were less likely to have had a cesarean delivery (N= 28 (28.0%) vs. N=40 (46.0%), $p=0.01$) or to have had meconium-stained amniotic fluid (N=1 (1.0%) vs. N= 6 (6.9%), $p=0.03$). After adjusting for potential confounders, only cesarean delivery remained independently associated with a decreased likelihood of receiving delayed cord clamping (aOR 0.49, 95% CI 0.25–0.96). There were no differences in delayed cord

clamping adherence by maternal age, parity, body mass index, race or ethnicity, insurance, or gestational age at delivery. In addition, there were no differences in delayed cord clamping adherence by clinical characteristics including use of neuraxial analgesia, receipt of antibiotics, magnesium or betamethasone, birthweight, 1-minute or 5-minute Apgar score, clinical diagnosis of abruption, or chorioamnionitis.

We then assessed whether neonates born after protocol introduction had outcomes different from those born before the protocol, regardless of protocol adherence. There were no significant differences in most maternal demographics, obstetric characteristics, or gestational age between the pre-protocol versus post-protocol cohorts (Table 2). Women in the post-protocol cohort, however, were more likely to have received neuraxial analgesia and magnesium neuroprophylaxis (88.2% vs. 77.9%, $p=0.005$; 94.7% vs 85.4%, $p=0.002$, respectively). On bivariable analyses, neonates in the post-protocol cohort were significantly less likely to require pharmacologic blood pressure support (Table 3). However, after adjustment for potential confounders, the presence of a new protocol, regardless of protocol adherence, did not have a statistically significant impact on neonatal outcomes between the pre-protocol and post-protocol cohorts.

Lastly, to assess the effect of delayed cord clamping adherence on neonatal outcomes, we performed a per-protocol analysis of neonatal outcomes comparing all neonates born pre-protocol to the subgroup of neonates born post-protocol who actually received the intervention (Table 4). Infants born after the protocol who received delayed cord clamping had higher birth hematocrit, fewer total number of red blood cell transfusions, lower frequency of red blood cell transfusions in the first week of life, and lower frequency of pressor support. In multivariable analysis, mean birth hematocrit, total number of blood transfusions, and proportion of infants requiring blood transfusion in the first week of life remained statistically significantly improved for infants receiving delayed cord clamping. No other neonatal outcomes were different between groups. Measures of potential harm in delayed cord clamping recipients, such as neonatal peak bilirubin, were not statistically significant.

DISCUSSION

Since the release of recommendations for delayed cord clamping by the College¹⁰, many hospitals have adopted institution-wide protocols. However, this intervention has yet to be adopted uniformly by all health care providers for preterm infants due to ongoing questions regarding the balance of need for immediate neonatal resuscitative efforts with benefits of delayed cord clamping. Our study accomplishes two goals with regard to this question. First, it addresses the quality improvement issue of provider adherence to the delayed cord clamping protocol within a single institution. We identified a pattern of improvement with delayed cord clamping performance following health care provider education and determined that cesarean delivery was an important factor that negatively influenced health care provider adherence with delayed cord clamping. Second, it provides further evidence in a real-life, large volume setting that introduction of a standardized protocol for performing delayed cord clamping in preterm, singleton infants <32 weeks gestational age is feasible, and associated with neonatal clinical benefits without evidence of adverse outcomes.

Previous randomized trials and meta-analyses have demonstrated the benefits of performing delayed cord clamping in the preterm infant.^{18,19} Similar to prior work, we found delayed cord clamping is associated with a higher birth hematocrit and reduced need for red blood cell transfusions in the first week of life compared to neonates born prior to the initiation of the protocol. Furthermore, we identified that delayed cord clamping is associated with a decrease in the total number of red blood cell transfusions required over the course of a neonate's hospitalization.^{20, 21} Multivariable analyses could not be performed for the outcomes of neonatal death, need for pharmacologic blood pressure support, or cord pH because there were no events in the cohort who received delayed cord clamping. Increases in magnesium prophylaxis administration and neuraxial analgesia across these two time periods may reflect impactful obstetric change over time despite the absence of any new or updated institutional practices regarding magnesium sulfate or neuraxial analgesia use during the study period, and were controlled for in analyzing neonatal outcomes. No other major institutional protocols changed during this period, suggesting the findings are not due to other policy changes. Notably, these differences were not evident when comparing all neonates in the post-protocol period (i.e., including those who did not receive delayed cord clamping despite eligibility) to those in the pre-protocol period, which suggests the differences identified in the per-protocol subgroup analysis can be related to performance of delayed cord clamping. Such findings suggest there may be even greater improvement in overall neonatal outcomes if adherence to the protocol improved.

Moreover, while delayed cord clamping has been demonstrated to benefit premature neonates, data in non-trial settings are lacking. Importantly, our data suggest benefits and lack of adverse outcomes associated with delayed cord clamping in a non-trial setting similar to those in a trial setting.^{7,8,18,19} Furthermore, our study suggests delayed cord clamping was not associated with inability to collect cord blood gases, as cord blood gases were still recorded for more than 70% of delayed cord clamping patients.

A central goal of this study was to identify areas for quality improvement and health care provider education. As is often seen with quality improvement initiatives, intermittent decrements in adherence occurred over time that were then reversed with further education. Continuous reeducation and support for delayed cord clamping are necessary to sustain these quality improvement changes. Importantly, cesarean delivery was the only factor significantly associated with failing to receive delayed cord clamping. We identified no difference in adherence to the protocol based on maternal demographic factors, clinical characteristics, or antepartum or intrapartum care, suggesting ongoing interventions to improve protocol performance should be directed at staff education during cesarean deliveries. We hypothesize that cesarean deliveries are associated with decreased likelihood of performing delayed cord clamping due to health care provider ambiguity towards optimal positioning of the infant, technique, and duration and timing of the procedure associated with this mode of delivery. Further, health care providers may have concerns about maternal bleeding from an open hysterotomy during the delay. Physician and nursing education on the neonatal benefits of delayed cord clamping regardless of route of delivery, including absence of data on maternal harm with delayed cord clamping during cesarean, likely will be essential to increasing health care provider comfort with and adherence to the protocol.

This study is unique in that it was performed at a high volume urban academic center with a diverse patient population. Additionally, while prior data have demonstrated the efficacy of delayed cord clamping in the setting of clinical trials, this study demonstrates the effectiveness of delayed cord clamping and the barriers to its use in a non-trial setting. Moreover, this institution is a high-volume delivery unit with over 120 delivering attending obstetricians, 51 residents and fellows, and hundreds of nursing staff, thus requiring substantial resources to introduce and disseminate a new practice. The demonstration of increasingly successful protocol introduction in this setting suggests such techniques can be applied in other similarly large and diverse settings. At the same time, our data show the sustained quality improvement efforts required to ensure reasonable, if not ideal, adherence to a new protocol. Our institution's experience may offer lessons for other institutions who are implementing or expanding a delayed cord clamping protocol. For example, the close collaboration of obstetrics, neonatology, and nursing was key to improving adherence; leadership from each of these clinical arenas frequently reinforced the importance of delayed cord clamping, performed specialty-specific education, and worked together to solve problems with protocol uptake. The inclusion of both formal (e.g. Grand Rounds), and informal (e.g. didactic lectures and discussions at team labor board sign-out) were also critical to improvement. Lastly, we did not perform individual health care provider feedback on performance of delayed cord clamping; one potential area for improvement would be to offer individual health care providers personalized feedback on their adherence to the protocol.

However, there are a number of limitations to consider. Although we attempted to account for significant differences between the pre- and post-protocol cohorts in the analyses, there may have been other unmeasured changes in practices over the 4-year study period for which we could not account, but there were no explicit policy changes in this time period. Unlike some previous trials, our analysis did not show a significant association between delayed cord clamping and the incidence of BPD, NEC, late-onset sepsis, or Grade III/IV IVH^{22,23}, however, our study was not powered to detect differences in these less common outcomes and thus the negative findings may not be generalizable. In addition to the set exclusion criteria for the study, neonates <32 weeks with major fetal anomalies, who were ineligible for intervention, or who required urgent intensive care were immediately transferred to the Children's Hospital after birth, and were not included in the study due to lack of available outcomes data following their transfer. Further, our data cannot identify reasons why delayed cord clamping was undertaken less frequently during cesarean deliveries, and whether there may have been additional reasons beyond health care provider knowledge and comfort. Additionally, these data do not address the optimal timing and duration of delayed cord clamping, as this may affect the benefit and outcomes of the procedure.^{23,24} While previous trials have cited between 30 to 90 seconds of delayed cord clamping, this is largely based on institution or health care provider preference. Comparison of duration of cord clamping on neonatal outcomes in future studies may address whether timing of the procedure results in increased benefit for the neonate. Finally, incorporating specific health care provider demographic data would be a valuable addition to the analysis and should be considered in future studies. A limitation of these data is the lack of specific health care provider demographic details; however, all health care providers in this study are

attending obstetricians with resident involvement in all preterm deliveries. Examining individual health care provider compliance rates to delayed cord clamping and directing education efforts towards these health care providers may further improve adherence.

In summary, our study provides further evidence that a delayed cord clamping protocol can be implemented in a high volume academic setting and that, when used, is associated with benefits in the very preterm infant. Education on delayed cord clamping, especially regarding performance during cesarean deliveries, may be required to improve health care provider adherence to the procedure.

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PRECIS

Adherence to a delayed cord clamping protocol for singleton neonates born at less than 32 weeks of gestation improves with continued health care provider education and is associated with lower frequency of neonatal blood transfusions.

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Figure 1.
Run chart. Each dot represents a percentage of protocol adherence.

Table 1

Factors associated with performance of delayed cord clamping in the post-protocol era

Characteristic	Bivariable Analysis			Multivariable Analysis*	
	Did not receive DCC N=87	Received DCC N=100	p-value	aOR	95% CI
Maternal age (years)	30.6 ± 6.6	30.3 ± 6.9	0.73		
Nulliparous	45 (51.7%)	57 (57.0%)	0.47		
Obese (BMI ≥ 30 kg/m ²)	30 (34.5%)	39 (39.0%)	0.52		
Race/ethnicity			0.06*		
Non-Hispanic white	32 (36.8%)	33 (33.0%)		(Ref)	
Non-Hispanic black	24 (27.6%)	24 (24.0%)		0.95	0.44–2.05
Hispanic	17 (19.5%)	11 (11.0%)		0.59	0.23–1.53
Other/unknown	14 (16.1%)	32 (32.0%)		2.10	0.93–4.75
Public insurance	33 (37.9%)	40 (40.0%)	0.77		
Gestational age (weeks)	29.2 ± 2.8	29.5 ± 2.0	0.56		
Cesarean delivery	40 (46.0%)	28 (28.0%)	0.01*	0.49	0.25–0.96
Neuraxial analgesia	80 (92.0%)	85 (85.0%)	0.14		
Antibiotics received before birth	79 (90.8%)	95 (95.0%)	0.26		
Magnesium prophylaxis received	81 (93.1%)	96 (96.0%)	0.38		
Full betamethasone course received	72 (82.8%)	86 (86.0%)	0.54		
Birthweight (grams)	1346.5 ± 516.6	1404.8 ± 440.1	0.41		
1 minute Apgar score <7	49 (56.3%)	43 (43.0%)	0.07*	0.74	0.38–1.42
5 minute Apgar score <7	21 (24.1%)	19 (19.0%)	0.40		
Clinical diagnosis of placental abruption	10 (11.5%)	7 (7.0%)	0.29		
Chorioamnionitis	7 (8.0%)	11 (11.0%)	0.50		
Meconium-stained amniotic fluid	6 (6.9%)	1 (1.0%)	0.03*	0.15	0.02–1.31

DCC, delayed cord clamping; aOR, adjusted odds ratio; CI, confidence interval

Data reported as N(%) or mean ± standard deviation.

* Adjusting for factors with p<0.1 on bivariate analysis

TABLE 2

Cohort demographic and clinical characteristics before and after delayed cord clamping protocol introduction

Characteristic	Pre-Protocol N=240	Post-Protocol N=187	p-value
Maternal age (years)	30.3 ± 6.2	30.4 ± 6.7	0.86
Nulliparous	137 (57.1%)	102 (54.5%)	0.60
Obese (BMI ≥ 30 kg/m ²)	95 (39.6%)	69 (36.9%)	0.57
Race/ethnicity			0.22
Non-Hispanic white	79 (32.9%)	65 (34.8%)	
Non-Hispanic black	83 (34.6%)	48 (25.7%)	
Hispanic	32 (13.3%)	28 (15.0%)	
Other/unknown	46 (19.2%)	46 (24.6%)	
Public insurance	96 (40.0%)	73 (39.0%)	0.84
Gestational age (weeks)	29.3 ± 2.4	29.4 ± 2.4	0.94
Cesarean delivery	102 (42.5%)	68 (36.4%)	0.20
Neuraxial analgesia	187 (77.9%)	165 (88.2%)	0.005
Antibiotics received before birth	222 (92.5%)	174 (93.0%)	0.83
Magnesium prophylaxis received	205 (85.4%)	177 (94.7%)	0.002
Full betamethasone course received	212 (88.3%)	158 (84.5%)	0.25
Birthweight (grams)	1318.4 ± 454.3	1377.7 ± 476.8	0.19
1 minute Apgar score <7	137 (57.1%)	92 (49.2%)	0.11
5 minute Apgar score <7	49 (20.4%)	40 (21.4%)	0.81
Clinical diagnosis of placental abruption	31 (12.9%)	17 (9.1%)	0.21
Chorioamnionitis	25 (10.4%)	18 (9.6%)	0.79
Meconium-stained amniotic fluid	12 (5.0%)	7 (3.7%)	0.53

BMI, body mass index

Data reported as N(%) or mean ± standard deviation.

TABLE 3

Neonatal outcomes before and after delayed cord clamping protocol introduction

Outcome	Bivariable Analysis			Multivariable Analysis*	
	Pre-Protocol N=240	Post-Protocol N=187	p-value		
				Linear Regression	
				β	p-value
Initial temperature (Celsius)	36.7 ± 2.4	36.2 ± 4.7	0.18	-0.62	0.08
Peak bilirubin (mg/dL)	6.8 ± 2.3	7.2 ± 2.6	0.08	0.34	0.16
Birth hematocrit (%)	44.8 ± 7.6	46.2 ± 8.9	0.08	1.16	0.15
Total number of blood transfusions	2.2 ± 5.0	1.5 ± 3.5	0.10	-0.49	0.26
				Logistic Regression	
				aOR	95% CI
Blood transfusion needed in 1 st week	57 (23.8%)	32 (17.1%)	0.09	0.69	0.42–1.14
Mechanical ventilation >7 days	40 (16.7%)	30 (16.0%)	0.86	1.02	0.60–1.73
Cord umbilical artery pH <7.0 (N=327)	8 (4.2%)	4 (2.9%)	0.53	0.70	0.20–2.35
5 minute Apgar score <7	49 (20.4%)	40 (21.4%)	0.81	1.15	0.71–1.87
Neonatal death	8 (3.3%)	5 (2.7%)	0.69	1.08	0.33–3.51
Need for pharmacologic blood pressure support	17 (7.1%)	5 (2.7%)	0.04	0.41	0.15–1.15
BPD	59 (24.6%)	44 (23.5%)	0.80	0.99	0.63–1.57
NEC	15 (6.3%)	8 (4.3%)	0.37	0.69	0.28–1.70
Late onset sepsis	13 (5.4%)	10 (5.3%)	0.98	1.08	0.46–2.58
Grade III/IV IVH	12 (5.0%)	5 (2.7%)	0.22	0.58	0.20–1.72

BPD, bronchopulmonary dysplasia; NEC, necrotizing enterocolitis; IVH, intraventricular hemorrhage; aOR, adjusted odds ratio; CI, confidence interval

Data reported as N(%) or mean ± standard deviation.

Cord umbilical artery pH < 7.0 (N=number of neonates for whom cord gases were collected)

* Adjusted for neuraxial analgesia and magnesium prophylaxis

Neonatal outcomes among neonates receiving delayed cord clamping after protocol implementation compared to pre-protocol period

TABLE 4

Outcome	Bivariable Analysis			Multivariable Analysis*	
	Pre-Protocol N=240	Received DCC in Post-Protocol Period N=100	p-value		
				Linear Regression	
				β	p-value
Initial temperature (Celsius)	36.7 $\pm$ 2.4	36.8 $\pm$ 0.4	0.82	-0.04	0.87
Peak bilirubin (mg/dL)	6.8 $\pm$ 2.3	7.1 $\pm$ 2.1	0.21	0.21	0.43
Birth hematocrit (%)	44.8 $\pm$ 7.6	47.5 $\pm$ 7.2	0.003	2.46	0.007
Total number of blood transfusions	2.2 $\pm$ 5.0	1.0 $\pm$ 2.3	0.003	-1.12	0.03
				Logistic Regression	
				aOR	95% CI
Blood transfusion needed in 1 st week	57 (23.8%)	13 (13.0%)	0.03	0.49	0.25–0.96
Mechanical ventilation >7 days	40 (16.7%)	14 (14.0%)	0.54	0.83	0.43–1.62
Cord umbilical artery pH <7.0 (N=262)**	8 (4.2%)	0 (0%)	0.07	–	–
5 minute Apgar score <7	49 (20.4%)	19 (19.0%)	0.77	0.99	0.55–1.83
Neonatal death**	8 (3.3%)	0 (0%)	0.07	–	–
Need for pharmacologic blood pressure support**	17 (7.1%)	0 (0%)	0.006	–	–
BPD	59 (24.6%)	17 (17.0%)	0.13	0.67	0.37–1.24
NEC	15 (6.3%)	5 (5.0%)	0.66	0.78	0.27–2.25
Late onset sepsis	13 (5.4%)	6 (6.0%)	0.83	1.18	0.43–3.27
Grade III/IV IVH	12 (5.0%)	2 (2.0%)	0.21	0.39	0.09–1.79

BPD, bronchopulmonary dysplasia; NEC, necrotizing enterocolitis; IVH, intraventricular hemorrhage; aOR, adjusted odds ratio; CI, confidence interval

Data reported as N(%) or mean $\pm$ standard deviation.

Cord umbilical artery pH < 7.0 (N=number of neonates for whom cord gases were collected)

* Adjusted for neuraxial analgesia and magnesium prophylaxis

** Unable to calculate odds ratio due to no cases in the post-protocol cohort that received DCC