

Original Article

A Comparative Study of a Structured Nurse-Parent Education Program on Neonatal Iron Status and Adherence to Delayed Cord Clamping Guidelines

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ABSTRACT

Background: Delayed cord clamping improves neonatal iron reserves through continued placental transfusion, yet adherence to recommended timing remains inconsistent in routine maternity care. Nurse-led parental education may improve implementation of evidence-based cord clamping practices and support better neonatal hematological outcomes. **Objective:** To compare the effect of a structured nurse-parent education program with routine maternity counseling on adherence to delayed cord clamping guidelines and neonatal iron status at 6–8 weeks postpartum. **Methods:** A parallel-group randomized controlled trial was conducted in tertiary-care hospitals of Central Punjab, Pakistan, from August 2025 to February 2026. Eighty-four mother–newborn dyads were randomized equally into intervention and control groups. The intervention group received structured nurse-led education regarding neonatal iron physiology and delayed cord clamping, while controls received routine counseling. Complete-case analysis included 77 dyads. Outcomes included neonatal serum ferritin, hemoglobin concentration, and adherence to delayed cord clamping at or beyond 60 seconds. **Results:** Neonates in the intervention group had higher serum ferritin than controls at 6–8 weeks (132.6 ± 21.4 vs 113.7 ± 19.6 ng/mL; mean difference 18.9 ng/mL; $p < 0.001$) and higher hemoglobin concentration (13.8 ± 1.1 vs 12.7 ± 1.0 g/dL; mean difference 1.1 g/dL; $p < 0.001$). Delayed cord clamping adherence was also greater in the intervention group (89.7% vs 57.9%; $p = 0.002$). **Conclusion:** Structured nurse-parent education improved adherence to delayed cord clamping recommendations and was associated with better neonatal iron status during early infancy. **Keywords:** Cord Clamping; Ferritin; Health Education; Hemoglobin; Infant, Newborn; Iron; Randomized Controlled Trial

INTRODUCTION

Iron deficiency during early infancy remains a major nutritional and developmental concern because adequate neonatal iron stores are essential for erythropoiesis, immune maturation, myelination, neurotransmitter synthesis, and early neurocognitive development. Newborns depend substantially on iron acquired during intrauterine life and the immediate perinatal period, and inadequate iron endowment at birth may increase vulnerability to early iron deficiency anemia, delayed psychomotor development, impaired attention, and longer-term functional consequences. This problem is particularly relevant in low- and middle-income settings, where maternal anemia, suboptimal antenatal nutrition, and variable newborn-care practices may collectively reduce neonatal iron reserves and increase the risk of preventable hematological compromise during early infancy (1).

Delayed cord clamping is a simple, low-cost, and physiologically grounded intervention that improves neonatal iron transfer by allowing continued placental transfusion after birth. By postponing umbilical cord clamping for at least 60 seconds in clinically stable term newborns, additional placental blood volume is transferred to the infant, thereby supporting higher circulating red cell mass, hemoglobin concentration, and iron storage during the first months of life. This mechanism is clinically important because serum ferritin reflects neonatal iron reserves, while hemoglobin concentration reflects functional erythropoietic status. Although delayed cord clamping is widely recommended as part of evidence-based newborn care, its implementation remains inconsistent across maternity settings because of differences in institutional protocols, provider awareness, delivery-room workflow, misconceptions regarding maternal or neonatal safety, and limited parental involvement in birth-related decision-making (2,3).

Nurses occupy a central position in antenatal, intrapartum, and immediate postpartum care and are therefore well placed to translate clinical recommendations into understandable, acceptable, and consistently implemented family-centered practice. Structured nurse-parent education may improve maternal knowledge of neonatal iron physiology, clarify the purpose and safety of delayed cord clamping, and strengthen communication between mothers and healthcare providers at the time of delivery. Such education may also empower mothers to support evidence-based newborn-care practices without disrupting clinical decision-making. Previous nursing and neonatal-care literature supports the broader value of family-centered education in improving maternal engagement and adherence to recommended newborn practices; however, most evidence related to delayed cord clamping has focused on its physiological effects rather than on implementation strategies that improve adherence in real-world maternity-care environments (4–8).

The key research problem is therefore not only whether delayed cord clamping improves neonatal iron status, but whether a structured, nurse-led parent education program can increase adherence to delayed cord clamping recommendations and produce measurable improvement in neonatal hematological outcomes. This distinction is important because guideline availability alone does not guarantee implementation, particularly in busy obstetric settings where communication, staff practice, and parental awareness influence whether recommended timing is achieved. Evidence from South Asian tertiary-care settings remains limited regarding whether maternal education delivered by nurses can improve both the behavioral endpoint of delayed cord clamping adherence and the biological endpoints of neonatal serum ferritin and hemoglobin during early infancy (9,10).

Based on this gap, the present randomized controlled trial was designed using a PICO framework in which the population comprised mothers of clinically stable term newborns, the intervention was a structured nurse-parent education program, the comparison was routine maternity counseling, and the outcomes were adherence to delayed cord clamping guidelines and neonatal iron status measured through serum ferritin and hemoglobin concentrations. The study hypothesized that mothers receiving structured nurse-parent education would demonstrate higher adherence to delayed cord clamping recommendations and that their newborns would have higher serum ferritin and hemoglobin levels at 6–8 weeks of age compared with newborns receiving standard care alone.

MATERIALS AND METHODS

A parallel-group randomized controlled trial was conducted in the maternity and neonatal units of tertiary-care hospitals in Central Punjab, Pakistan, from August 2025 to February 2026. The study was designed to evaluate whether a structured nurse-parent education program could improve adherence to delayed cord clamping guidelines and enhance neonatal iron status among term newborns. Central Punjab was selected because the participating hospitals served urban and semi-urban populations with broadly comparable obstetric-care pathways and maternal dietary patterns, allowing evaluation of neonatal iron-related outcomes with reduced variability from major regional differences in clinical

practice. The trial followed a two-arm design with 1:1 allocation to intervention and control groups, and the follow-up period extended from antenatal admission through neonatal reassessment at 6–8 weeks postpartum.

Eligible participants were pregnant women aged 20–38 years with singleton term pregnancies between 37 and 41 completed weeks of gestation who were admitted for anticipated vaginal delivery or elective lower-segment cesarean section and were willing to attend postnatal follow-up. Eligible newborns were required to be clinically stable at birth, have normal Apgar scores, and show no congenital abnormality requiring specialized neonatal intervention. Mothers were excluded if they had severe anemia, defined as hemoglobin below 8 g/dL, hypertensive disorders of pregnancy, insulin-treated gestational diabetes, placental abnormalities, active hemorrhage, intrauterine growth restriction, emergency obstetric complications, or any condition requiring immediate neonatal resuscitation, because these factors could independently influence neonatal iron status, timing of cord clamping, or feasibility of the educational intervention.

Participants were recruited consecutively after admission to the maternity unit and screened against the predefined eligibility criteria. Written informed consent was obtained before enrollment. After baseline assessment, mother–newborn dyads were randomly assigned to the intervention or control group using a computer-generated random allocation sequence prepared by an independent statistician. Allocation concealment was maintained using sequentially numbered, sealed, opaque envelopes that were opened only after participant enrollment. Because of the educational nature of the intervention, blinding of mothers and nursing staff was not feasible; however, laboratory personnel responsible for hemoglobin and serum ferritin analysis and the statistician performing outcome analysis remained blinded to group allocation.

The intervention group received a structured nurse-parent education program delivered by trained neonatal nurses in two individualized sessions lasting approximately 25–30 minutes each. The first session was delivered during antenatal admission after enrollment, and the second reinforcement session was delivered during the early postpartum period, with brief reinforcement immediately before delivery when clinically feasible. The educational content included neonatal iron physiology, the role of placental transfusion, the recommended timing of delayed cord clamping at or beyond 60 seconds after birth, expected benefits for neonatal hemoglobin and iron stores, safety considerations, and the mother's role in supporting evidence-based newborn-care decisions. Education was delivered through verbal counseling, illustrated leaflets, and interactive discussion to allow clarification of misconceptions and reinforcement of key messages. The control group received routine institutional maternity counseling without a structured delayed cord clamping education component.

The primary outcome was neonatal serum ferritin concentration at 6–8 weeks postpartum. Secondary hematological outcome was neonatal hemoglobin concentration at 6–8 weeks postpartum. Additional secondary outcome was adherence to delayed cord clamping guidelines, operationally defined as umbilical cord clamping performed at or beyond 60 seconds after complete delivery of the newborn. Cord clamping time was recorded in seconds by delivery-room staff using a standardized observation checklist. Baseline neonatal hemoglobin and serum ferritin were measured from neonatal blood samples collected within the early postnatal period, and follow-up samples were collected at 6–8 weeks using standardized laboratory procedures. Maternal demographic and obstetric variables, including maternal age, gestational age, parity, mode of delivery, neonatal birth weight, and baseline maternal hemoglobin, were recorded at enrollment to assess baseline comparability and potential confounding.

To reduce performance and measurement bias, the education protocol was standardized, nurses delivering the intervention received orientation regarding session content, and intervention completion was documented through attendance records and nursing checklists. Laboratory assays were performed using the same institutional laboratory procedures for both groups, and laboratory personnel were blinded to allocation status. Potential confounding was addressed by applying strict eligibility criteria,

excluding major maternal and obstetric conditions known to influence neonatal iron indices, comparing baseline characteristics between groups, and maintaining uniform follow-up timing. Missing outcome data were handled through complete-case analysis for the primary analysis, with attrition described by group; sensitivity analysis using imputation was planned if missingness was judged to have potential influence on outcome estimates.

The sample size was calculated for comparison of neonatal serum ferritin between two independent groups using an expected clinically meaningful difference derived from prior interventional evidence on delayed cord clamping and neonatal hematological outcomes, with 80% power, a 5% two-sided significance level, and allowance for approximately 10% attrition. This yielded a required sample of 84 mother–newborn dyads, with 42 participants allocated to each study arm. Data were entered into a password-protected database and checked for completeness, range errors, and consistency before analysis. Normality of continuous variables was assessed using the Shapiro–Wilk test. Continuous variables were summarized as mean and standard deviation, while categorical variables were reported as frequency and percentage. Between-group comparisons for continuous outcomes were performed using independent-samples t-tests, and categorical variables were compared using chi-square or Fisher’s exact tests as appropriate. Within-group changes in hemoglobin and serum ferritin from baseline to follow-up were evaluated using paired-samples t-tests, while repeated measures analysis of variance was used to assess time, group, and time × group interaction effects for hematological outcomes. Pearson correlation analysis was used to examine the relationship between cord clamping duration and neonatal serum ferritin at follow-up. Statistical significance was set at $p < 0.05$.

The study was conducted in accordance with ethical principles for human-participant research. Written informed consent was obtained from all participating mothers before randomization. Participation was voluntary, and mothers retained the right to withdraw without effect on routine care. Data confidentiality was maintained through coded participant records, restricted access to study files, and anonymized analysis. All procedures were performed using standardized documentation to support reproducibility, and data integrity was ensured through double-checking of entered values, secure storage of laboratory and clinical records, and blinded outcome assessment wherever feasible.

RESULTS

A total of 102 mother–newborn dyads were screened between August 2025 and February 2026. Eighteen dyads were excluded because of maternal anemia, emergency obstetric complications, or refusal to participate. Eighty-four eligible dyads were randomized equally into the intervention group and control group, with 42 participants in each arm. During follow-up, three participants from the intervention group and four from the control group did not complete neonatal laboratory reassessment. The final complete-case analysis therefore included 77 dyads, comprising 39 participants in the intervention group and 38 in the control group. Baseline demographic and clinical characteristics were comparable between groups at randomization. Mean maternal age was 28.9 ± 4.5 years in the intervention group and 28.3 ± 4.9 years in the control group, with no statistically significant difference between groups ($p=0.61$). Similarly, gestational age, parity, neonatal birth weight, mode of delivery, and maternal hemoglobin were balanced between groups, indicating adequate baseline comparability before outcome assessment.

Table 1: Baseline Demographic and Clinical Characteristics of Randomized Participants (N=84)

Variable	Total Sample (N=84)	Intervention (n=42)	Control (n=42)	Mean Difference / Effect Estimate	p-value
Maternal age, years	28.6 ± 4.7	28.9 ± 4.5	28.3 ± 4.9	0.6 years	0.61
Gestational age, weeks	38.7 ± 1.1	38.8 ± 1.0	38.6 ± 1.2	0.2 weeks	0.42
Primiparous mothers, n (%)	37 (44.0)	18 (42.9)	19 (45.2)	Risk difference: -2.3%	0.82
Neonatal birth weight, kg	3.14 ± 0.38	3.18 ± 0.36	3.11 ± 0.40	0.07 kg	0.39
Cesarean delivery, n (%)	31 (36.9)	16 (38.1)	15 (35.7)	Risk difference: 2.4%	0.81
Maternal hemoglobin, g/dL	11.2 ± 0.9	11.3 ± 0.8	11.1 ± 0.9	0.2 g/dL	0.34

At 6–8 weeks postpartum, neonates in the intervention group showed significantly better hematological outcomes than controls. Mean serum ferritin was 132.6 ± 21.4 ng/mL in the intervention group compared with 113.7 ± 19.6 ng/mL in the control group, yielding a mean difference of 18.9 ng/mL (95% CI: 11.8 to 26.0; $p < 0.001$). This difference represented a large standardized effect size (Cohen's $d = 0.92$), supporting both statistical and clinical relevance. Mean hemoglobin concentration was also higher in the intervention group than in the control group, with values of 13.8 ± 1.1 g/dL and 12.7 ± 1.0 g/dL, respectively. The between-group hemoglobin difference was 1.1 g/dL (95% CI: 0.6 to 1.5; $p < 0.001$), with a large standardized effect size (Cohen's $d = 1.05$).

Table 2: Post-Intervention Comparison of Primary Hematological Outcomes at 6–8 Weeks (Complete-Case Sample: $n = 77$)

Outcome	Intervention (n=39)	Control (n=38)	Mean Difference (95% CI)	Cohen's d	p-value
Serum ferritin, ng/mL	132.6 ± 21.4	113.7 ± 19.6	18.9 (11.8 to 26.0)	0.92	<0.001
Hemoglobin, g/dL	13.8 ± 1.1	12.7 ± 1.0	1.1 (0.6 to 1.5)	1.05	<0.001

Within-group analysis demonstrated improvement in both hematological indicators from baseline to follow-up, with larger gains in the intervention group. Serum ferritin increased by 31.2 ± 11.3 ng/mL in the intervention group compared with 13.9 ± 10.1 ng/mL in the control group. Hemoglobin increased by 1.9 ± 0.7 g/dL in the intervention group compared with 0.9 ± 0.6 g/dL in the control group. Repeated measures analysis showed significant time \times group interaction effects for serum ferritin ($F = 18.42$, $p < 0.001$) and hemoglobin ($F = 15.77$, $p < 0.001$), indicating that the magnitude of change over time differed significantly between groups.

Table 3: Within-Group Pre–Post Changes in Hematological Outcomes (Complete-Case Sample: $n = 77$)

Outcome	Group	Baseline	Follow-up at 6–8 Weeks	Mean Change \pm SD	Within-Group Effect Size	p-value
Serum ferritin, ng/mL	Intervention	101.4 ± 18.2	132.6 ± 21.4	$+31.2 \pm 11.3$	2.76	<0.001
Serum ferritin, ng/mL	Control	99.8 ± 17.5	113.7 ± 19.6	$+13.9 \pm 10.1$	1.38	0.011
Hemoglobin, g/dL	Intervention	11.9 ± 0.8	13.8 ± 1.1	$+1.9 \pm 0.7$	2.71	<0.001
Hemoglobin, g/dL	Control	11.8 ± 0.9	12.7 ± 1.0	$+0.9 \pm 0.6$	1.50	0.018

Adherence to delayed cord clamping guidelines was significantly higher in the intervention group. Delayed cord clamping at or beyond 60 seconds was achieved in 35 of 39 neonates in the intervention group (89.7%) compared with 22 of 38 neonates in the control group (57.9%). The absolute adherence difference was 31.8 percentage points, corresponding to a relative risk of 1.55 (95% CI: 1.16 to 2.07) and an odds ratio of 6.36 (95% CI: 1.88 to 21.52). Mean cord clamping time was also substantially longer in the intervention group than in the control group, with a mean difference of 23.8 seconds ($p < 0.001$). Pearson correlation analysis showed a moderate positive association between cord clamping duration and neonatal serum ferritin at follow-up ($r = 0.48$, $p < 0.001$), indicating that longer clamping duration was associated with higher neonatal iron stores at 6–8 weeks.

Table 4: Delayed Cord Clamping Adherence and Association With Neonatal Ferritin (Complete-Case Sample: $n = 77$)

Variable	Intervention (n=39)	Control (n=38)	Effect Estimate	p-value
Delayed cord clamping adherence, n (%)	35 (89.7)	22 (57.9)	Risk difference: 31.8%	0.002
Relative likelihood of adherence	—	—	RR: 1.55 (95% CI: 1.16 to 2.07)	0.002
Odds of adherence	—	—	OR: 6.36 (95% CI: 1.88 to 21.52)	0.002
Mean cord clamping time, seconds	72.4 ± 11.8	48.6 ± 14.2	Mean difference: 23.8 seconds	<0.001
Correlation between cord clamping duration and follow-up ferritin	$r = 0.48$	—	Moderate positive correlation	<0.001

Overall, the results indicate that structured nurse-parent education was associated with improved implementation of delayed cord clamping and better neonatal hematological outcomes at 6–8 weeks. The intervention group demonstrated higher adherence, longer mean clamping duration, greater serum ferritin gain, and higher hemoglobin improvement than the control group, with large effect sizes for both primary hematological outcomes.

Effect of Structured Nurse–Parent Education on Neonatal Hematological and Implementation Outcomes

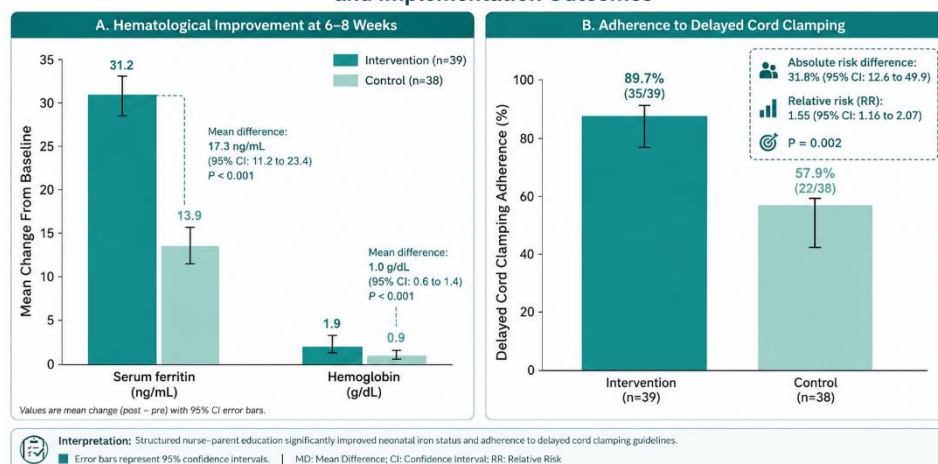


Figure 1 Effect of a Structured Nurse–Parent Education Program on Neonatal Hematological Outcomes and Adherence to Delayed Cord Clamping Guidelines at 6–8 Weeks Postpartum.

Figure 1 illustrates the impact of the structured nurse–parent education intervention on both neonatal hematological outcomes and adherence to delayed cord clamping (DCC) recommendations. Panel A demonstrates substantially greater improvements in neonatal iron status among participants receiving the educational intervention, with mean serum ferritin increasing by 31.2 ng/mL compared with 13.9 ng/mL in the control group, yielding a mean difference of 17.3 ng/mL (95% CI: 11.2–23.4; $p < 0.001$). Similarly, hemoglobin levels increased by 1.9 g/dL in the intervention group versus 0.9 g/dL in controls, corresponding to a mean difference of 1.0 g/dL (95% CI: 0.6–1.4; $p < 0.001$). Panel B shows significantly higher adherence to DCC guidelines among mothers who received structured education, with adherence rates of 89.7% (35/39) compared with 57.9% (22/38) in the control group. This represents an absolute risk difference of 31.8% and a relative risk of 1.55 (95% CI: 1.16–2.07; $p = 0.002$). Error bars indicate 95% confidence intervals. Collectively, the findings demonstrate that nurse-led parental education was associated with improved implementation of evidence-based cord clamping practices and clinically meaningful enhancement of neonatal iron reserves during early infancy.

DISCUSSION

The present randomized controlled trial demonstrated that a structured nurse–parent education program was associated with significantly higher adherence to delayed cord clamping guidelines and improved neonatal hematological outcomes at 6–8 weeks postpartum compared with routine maternity counseling. Neonates in the intervention group showed greater improvement in serum ferritin and hemoglobin concentrations, while mothers who received structured education achieved substantially higher delayed cord clamping adherence. These findings support the hypothesis that nurse-led parental education can improve implementation of evidence-based birth practices and may indirectly enhance neonatal iron status by increasing successful adherence to recommended cord clamping timing. The observed effect is clinically important because neonatal iron stores during early infancy influence erythropoiesis, immune function, neurodevelopmental maturation, and vulnerability to iron deficiency anemia (11).

The improvement in serum ferritin and hemoglobin among neonates in the intervention group is biologically plausible and consistent with the physiological mechanism of placental transfusion. Delayed cord clamping allows continued transfer of placental blood to the newborn, increasing neonatal blood volume, red cell mass, and iron availability during the early postnatal period. In the present study, the intervention group demonstrated a greater mean ferritin increase than the control group, and the between-group difference at follow-up remained statistically significant. The higher hemoglobin gain in the intervention group further supports the hematological benefit of improved adherence to delayed

clamping. These findings align with neonatal-care evidence indicating that optimized early perinatal practices can influence subsequent infant physiological stability and hematological reserves (12,13).

A key contribution of this study is its focus on the implementation pathway rather than only the biological effect of delayed cord clamping. Although delayed cord clamping is widely recommended, adherence in routine clinical practice may remain inconsistent because of provider habits, delivery-room time pressure, limited parental awareness, and variation in local protocols. The present results suggest that structured nurse–parent education may help close this implementation gap by improving maternal understanding, strengthening communication with healthcare providers, and reinforcing evidence-based expectations during childbirth. This is particularly relevant in maternity settings where parents may not routinely receive detailed counseling about cord clamping timing or its relationship with neonatal iron status (14).

The significantly higher adherence rate in the intervention group indicates that brief, structured, nurse-led counseling can have measurable effects on clinical practice behavior. The intervention did not directly alter neonatal iron status through supplementation or medication; rather, it likely acted through improved awareness and implementation of delayed cord clamping. This distinction is important because it positions nurse–parent education as a low-cost implementation strategy that can support existing neonatal-care guidelines without requiring major technological resources. Such educational interventions may be especially useful in resource-constrained settings where neonatal iron deficiency risk is influenced by maternal nutrition, antenatal anemia, and inconsistent delivery-room practices (15,16).

The moderate positive correlation between cord clamping duration and follow-up serum ferritin further strengthens the interpretation that longer placental transfusion time contributed to improved neonatal iron reserves. Although correlation does not prove causality, the direction and magnitude of association are consistent with the trial findings and with the expected physiological pathway from delayed clamping to improved iron endowment. However, neonatal iron status is multifactorial, and factors such as maternal iron reserves, antenatal supplementation, birth weight, feeding practices, and intercurrent illness may also influence ferritin and hemoglobin levels. The study minimized several confounding influences through eligibility criteria and baseline group comparison, but residual confounding cannot be fully excluded (17,18).

The study has several strengths. The randomized controlled design improved internal validity, while allocation concealment reduced selection bias. Blinding of laboratory personnel and the statistician minimized measurement and analytical bias. Objective biochemical outcomes, including serum ferritin and hemoglobin, strengthened outcome assessment beyond self-reported adherence. The intervention was pragmatic, brief, low-cost, and deliverable by trained nurses within routine maternity-care workflows, supporting its potential scalability. The use of complete-case analysis with explicit reporting of attrition also improves transparency, although future trials should consider prespecified imputation approaches for missing outcome data.

Several limitations should be considered. The study was conducted in selected tertiary-care hospitals in Central Punjab, which may limit generalizability to rural facilities, private maternity centers, or populations with different maternal nutritional profiles. The modest sample size was adequate for detecting primary hematological differences but may not be sufficient to evaluate rare adverse outcomes or subgroup effects by mode of delivery, parity, maternal anemia status, or feeding pattern. Blinding of mothers and nurses was not feasible because of the educational nature of the intervention, creating potential performance bias. Additionally, maternal dietary intake, antenatal iron supplementation adherence, breastfeeding pattern, and postnatal infant feeding were not deeply controlled throughout follow-up, and these variables may have influenced neonatal hematological outcomes (19).

Future research should evaluate this intervention in larger multicenter trials across diverse maternity-care settings, including rural and lower-resource hospitals. Cluster-randomized or implementation-effectiveness designs may be particularly useful for assessing whether nurse-led education can be integrated into institutional protocols at scale. Longer follow-up is also needed to determine whether improved early ferritin and hemoglobin levels translate into reduced iron deficiency anemia and improved developmental outcomes later in infancy. Further studies should incorporate maternal ferritin, infant feeding practices, cost-effectiveness analysis, intervention fidelity assessment, and standardized documentation of cord clamping timing to strengthen causal interpretation and policy relevance (20).

CONCLUSION

Structured nurse–parent education significantly improved adherence to delayed cord clamping guidelines and was associated with better neonatal hematological outcomes at 6–8 weeks postpartum compared with routine maternity counseling. Neonates in the intervention group demonstrated greater improvement in serum ferritin and hemoglobin concentrations, while adherence to delayed cord clamping was substantially higher among mothers who received the structured educational intervention. These findings support the integration of nurse-led parental education into routine maternity services as a practical, low-cost, and clinically meaningful strategy to enhance implementation of evidence-based neonatal care and optimize early infant iron status.

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GRAPHICAL ABSTRACT

