

Original article

Effect of Early *versus* Late Cord Clamping Post C/S in Term Infants on Hematological Status at Elmagrife Medical Center, Ajdabiya

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Abstract

Delayed cord clamping (DCC) allows continued placental transfusion after birth and may improve neonatal hematological status. This study aimed to compare the effects of early cord clamping (ECC) and DCC on hemoglobin and hematocrit levels in term infants delivered by cesarean section at Al-Magryaf Teaching Hospital. A randomized controlled trial was conducted among 100 women undergoing full-term cesarean section at the Department of Obstetrics and Gynecology, Al-Magryaf Teaching Hospital, from September 2023 to February 2024. Participants were randomly allocated to ECC, with cord clamping within 15 seconds of delivery, or DCC, with clamping after 1 minute. Neonatal blood samples were collected at birth and 24 hours later to assess hemoglobin, hematocrit, mean corpuscular volume, serum ferritin, and total bilirubin. Apgar scores and neonatal clinical outcomes were also recorded. Data were analyzed using SPSS version 25, with $p \leq 0.05$ considered statistically significant. Maternal and baseline neonatal characteristics were generally comparable between the two groups. DCC was associated with significantly higher neonatal hemoglobin and hematocrit levels at birth and at 24 hours. At birth, mean hemoglobin was 16.9 ± 2.0 g/dL in the DCC group compared with 15.1 ± 1.9 g/dL in the ECC group ($p < 0.0001$), while hematocrit was $45.9 \pm 7.5\%$ versus $41.5 \pm 5.5\%$, respectively ($p = 0.001$). At 24 hours, hemoglobin remained significantly higher with DCC (17.7 ± 1.9 vs. 15.5 ± 1.6 g/dL, $p < 0.0001$), as did hematocrit ($48.8 \pm 9.0\%$ vs. $44.2 \pm 8.9\%$, $p = 0.014$). Serum ferritin was also significantly higher after 24 hours in the DCC group (251.9 ± 172.8 vs. 180.3 ± 74.9 ng/mL, $p = 0.008$). DCC was associated with significantly better Apgar scores at 1 and 2 minutes, while no significant differences were observed in 5-minute Apgar scores, respiratory distress, or resuscitation. Total bilirubin and MCV did not differ significantly between groups. Delayed cord clamping for at least one minute in term infants delivered by cesarean section significantly improved early neonatal hemoglobin, hematocrit, and 24-hour ferritin levels without evidence of increased bilirubin levels or adverse neonatal outcomes. DCC appears to be a beneficial and safe practice and should be considered in routine management of stable term neonates undergoing cesarean delivery.

Keywords. Delayed, Early, Cord, Clamping, Term Neonates, Hematological.

Introduction

Umbilical cord clamping and cutting immediately after birth has been practiced for centuries; however, the optimal timing of cord clamping has remained controversial. Historically, early cord clamping was generally defined as clamping within the first minute after birth, whereas late clamping referred to clamping more than five minutes after delivery. More recently, early clamping has commonly been performed within the first 30 seconds, while delayed clamping generally refers to waiting for at least 30–60 seconds or longer before clamping. Some definitions describe immediate clamping as occurring within the first few seconds after birth, although this terminology is not universally accepted [1,2]. The physiological basis for delayed cord clamping is the transfer of blood from the placenta to the newborn during the first few minutes after birth. Studies of neonatal blood-volume changes have demonstrated that approximately 80–100 mL of blood may be transferred from the placenta to a healthy term infant within the first three minutes, with most of this transfusion occurring during the infant's initial breaths. In general, fetal blood volume is approximately 70 mL/kg, while the placenta contains about 45 mL/kg of fetal blood. Delaying cord clamping can therefore provide an additional 20–35 mL/kg of blood to the newborn, potentially increasing neonatal blood volume by as much as 50% [1,3].

Growing evidence indicates that delayed umbilical cord clamping provides important benefits for both term and preterm infants. In term neonates, delayed clamping is associated with higher hemoglobin concentrations during the first 24–48 hours of life and greater iron stores during the first 3–6 months. The additional red blood cell volume may increase neonatal iron reserves by approximately 30–50 mg and consequently reduce the risk of iron-deficiency anemia during infancy. Some studies have also suggested potential benefits for neurodevelopmental outcomes during early childhood [1,4–7]. In preterm infants, delayed cord clamping has been associated with several favorable neonatal outcomes, including reduced rates of intraventricular hemorrhage and necrotizing enterocolitis, as well as a lower requirement for blood transfusion. These findings have contributed to the increasing adoption of delayed cord clamping as part of routine neonatal care [1].

Historically, early clamping was favored because it was believed to reduce the risk of neonatal complications such as polycythemia, hyperviscosity, hyperbilirubinemia, and transient tachypnea. It was also recommended in certain clinical circumstances, including multiple pregnancies and deliveries involving mothers with HIV infection. However, accumulating evidence has challenged the routine use of immediate clamping and has highlighted the physiological and hematological advantages of allowing placental transfusion to continue after birth [3]. The management of the third stage of labor has also influenced the timing of cord clamping. Although active management is widely used to reduce excessive maternal blood loss, cord clamping has traditionally been performed very early as part of this approach. Current evidence, however, supports allowing a period of placental transfusion before clamping when the clinical condition of the mother and newborn permits. The American College of Obstetricians and Gynecologists recommended in 2017 that the umbilical cord should

generally not be clamped for at least 30–60 seconds after birth in both term and preterm infants, regardless of the mode of delivery [2,8]. The timing of cord clamping may also be particularly relevant following cesarean delivery. Previous studies have suggested that cesarean birth may be associated with reduced placental transfusion and lower neonatal iron stores, partly because early cord clamping is frequently performed during surgical delivery. Nevertheless, the relative effects of early and delayed clamping on neonatal hematocrit following cesarean section remain incompletely established [9]. Currently, there is a growing tendency toward delaying cord clamping for approximately two to three minutes after birth or until cord pulsations cease, when clinically appropriate. This approach may enhance neonatal hemoglobin and hematocrit levels, improve iron stores, facilitate early mother–infant contact, and reduce certain complications among preterm infants. Given these potential benefits, further investigation into the optimal timing of umbilical cord clamping is warranted. In particular, the limited evidence available from Ajdabiya highlights the need for local research to determine the effects of cord-clamping practices on neonatal hematological status. Such evidence may help inform the development of a cost-effective local protocol for cord clamping and contribute to the prevention of iron-deficiency anemia among infants in the study population.

A randomized clinical trial involving 120 healthy term infants compared early and delayed cord clamping. Delayed cord clamping resulted in significantly higher hemoglobin and hematocrit levels during the first 24–48 hours, with no significant increase in symptomatic polycythemia, although a slight increase in neonatal jaundice was observed. The findings indicated that delayed clamping improves neonatal hematological status and iron reserves and is a safe practice in healthy term infants [10]. A single-center randomized controlled trial evaluating term infants found that delayed clamping was associated with significantly higher ferritin levels at four months and a higher head-circumference percentile, without increasing the risks of hypothermia, polycythemia, or hyperbilirubinemia. These findings support delayed cord clamping as a safe approach that may help protect term infants against iron-deficiency anemia [11]. A systematic review and meta-analysis of 25 studies examining delayed versus early cord clamping during cesarean delivery demonstrated that delayed clamping was associated with improved neonatal hematocrit and bilirubin outcomes. No significant differences were observed in maternal blood loss, postpartum hemorrhage, transfusion requirements, or other major maternal outcomes, suggesting that delayed clamping improves selected neonatal outcomes without increasing adverse maternal effects [12]. Similarly, a randomized controlled trial involving 70 term neonates demonstrated significantly higher mean hemoglobin concentrations in infants who underwent delayed clamping compared with those who underwent early clamping (16.34 ± 1.90 vs. 13.84 ± 1.74 g/dL, respectively). These findings suggest that delayed cord clamping improves neonatal hemoglobin levels and may contribute to the prevention of anemia during infancy [13]. Another randomized controlled trial comparing clamping within 30 seconds with clamping at two minutes after birth found no significant difference in neonatal hemoglobin at birth; however, hemoglobin levels at 48 hours were significantly higher among infants who underwent delayed clamping. This finding highlights the potential early postnatal hematological benefits of delayed cord clamping in term neonates [14]. Evidence from term infants delivered by elective cesarean section also demonstrated that delaying cord clamping from within 30 seconds to 60 seconds after birth was associated with beneficial neonatal outcomes, including a lower risk of anemia at three months and improved Apgar scores. The findings support delayed cord clamping as a feasible, safe, and beneficial practice for term neonates [15]. Furthermore, a prospective observational study involving term neonates delivered vaginally or by cesarean section found that delayed clamping was associated with significantly higher hemoglobin and packed cell volume levels at 48 hours.

Serum bilirubin levels did not differ significantly between the groups, and delayed clamping was not associated with a significant increase in polycythemia or hyperbilirubinemia. These findings further support the hematological benefits of delayed cord clamping without substantial neonatal adverse effects [16]. In preterm infants born between 30 and 36 weeks of gestation, delaying cord clamping for more than two minutes resulted in significantly higher hematocrit and serum ferritin levels at six weeks compared with immediate clamping, although the duration of phototherapy was longer. Overall, the findings demonstrated that delayed cord clamping improves neonatal hematological status and may provide sustained benefits during early infancy [17].

Methods

Study Design

This study was designed as a randomized controlled trial.

Study Participants and Setting

The study included all women admitted to the Department of Obstetrics and Gynecology at Al-Magryaf Teaching Hospital who underwent full-term cesarean section (C/S) during six months, from 1 September 2023 to 28 February 2024.

Study Procedure

A detailed medical and obstetric history was obtained from all participants. Demographic characteristics and relevant obstetric data were recorded using a structured data collection sheet (Appendix I). After obtaining informed consent, participants were randomly allocated into two groups according to the timing of umbilical cord clamping:

- Early cord clamping (ECC) group: the umbilical cord was clamped within 15 seconds after delivery.
- Delayed cord clamping (DCC) group: the umbilical cord was clamped after 1 minute following delivery.

Blood samples were collected from the newborns immediately after birth and again at 24 hours of age. Laboratory investigations included a complete blood count (CBC), with assessment of hemoglobin (Hb, g/dL), hematocrit (HCT, %), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH, g/dL), and total serum bilirubin (TSB).

Data Collection

All required maternal and neonatal information was recorded using the structured data collection proforma presented in Appendix I.

Data Analysis

Data were entered, coded, and analyzed using the Statistical Package for the Social Sciences (SPSS), version 25. Descriptive statistics included means, standard deviations, frequencies, and percentages. Inferential statistical tests included the independent-samples t-test and Fisher's exact test, as appropriate. A p-value ≤ 0.05 was considered statistically significant.

Results

(Table 1) presents the maternal sociodemographic and clinical characteristics of the participants according to cord-clamping group. The mean maternal age was comparable between the early and delayed cord-clamping groups (31.9 ± 6.2 and 32.4 ± 4.7 years, respectively), with no statistically significant difference between the groups ($p = 0.651$). Most participants were Libyan (90.0%), and the majority were residents of Ajdabiya (80.0%). There were no statistically significant differences between the two groups regarding nationality ($p = 0.712$) or residence ($p = 0.413$). Regarding educational level, a statistically significant difference was observed between the groups ($p = 0.020$), indicating that educational attainment differed according to cord-clamping group. Housewives constituted the largest occupational category (68.0%), followed by teachers (16.0%) and nurses (8.0%). However, occupation did not differ significantly between the two groups ($p = 0.101$). Regarding medical history, hypertension was reported in 10.0% of participants, diabetes in 4.0%, and asthma in 2.0%, with no statistically significant difference between the cord-clamping groups. Similarly, surgical history did not differ significantly between the groups ($p = 0.813$). Previous cesarean section was the most frequently reported surgical history (54.0%), followed by no previous surgery (34.0%), cholecystectomy (8.0%), appendectomy (4.0%), and open-heart surgery (2.0%).

Table 1. Maternal sociodemographic and clinical characteristics according to cord-clamping group

Variable	Early cord clamping n (%)	Delayed cord clamping n (%)	P-value
Age (years)			NS
21–25	12 (24.0)	5 (10.0)	
26–30	6 (12.0)	10 (20.0)	
31–35	19 (38.0)	22 (44.0)	
36–40	7 (14.0)	12 (24.0)	
>40	6 (12.0)	1 (2.0)	
Mean $\pm$ SD	31.9 ± 6.2	32.4 ± 4.7	
Nationality			NS
Libyan	45 (90.0)	47 (94.0)	
Non-Libyan	5 (10.0)	3 (6.0)	
Residence			NS
Ajdabiya	40 (80.0)	44 (88.0)	
Outside Ajdabiya	10 (20.0)	6 (12.0)	
Education			0.020*
Primary	10 (20.0)	2 (4.0)	
Secondary	18 (36.0)	15 (30.0)	
University	22 (44.0)	33 (66.0)	
Occupation			NS
Nurse	4 (8.0)	3 (6.0)	
Housewife	34 (68.0)	27 (54.0)	
Pharmacist	1 (2.0)	0	
Teacher	8 (16.0)	12 (24.0)	
Employee	2 (4.0)	6 (12.0)	
Self-employed	1 (2.0)	0	
Medical history			NS
Hypertension	5 (10.0)	5 (10.0)	

Diabetes	2 (4.0)	6(12.0)	
Asthma	1 (2.0)	0	
Surgical history			NS
None	17 (34.0)	19(38.0)	
Previous C/S	27 (54.0)	27(54.0)	
Cholecystectomy	4 (8.0)	3(6.0)	
Appendectomy	2 (4.0)	1(2.0)	
Open-heart surgery	1 (2.0)	0	

(Table 2) summarizes the maternal obstetric characteristics and indications for cesarean section among women undergoing early versus delayed cord clamping. A statistically significant difference was observed in gravidity between the two groups ($P = 0.017$). Most women in the early cord-clamping group had 1–5 previous pregnancies (44, 88.0%), compared with 33 (66.0%) in the delayed cord-clamping group. Conversely, gravidity >5 was more frequent among women in the delayed cord-clamping group (17, 34.0%) than in the early cord-clamping group (6, 12.0%). Similarly, a statistically significant difference was observed regarding history of abortion ($P = 0.017$).

A previous abortion was reported in 6 women (12.0%) in the early cord-clamping group compared with 17 women (34.0%) in the delayed cord-clamping group. No significant difference was found in parity between the two groups ($P > 0.05$), with the majority of participants having 1–5 previous births in both groups (82.0% and 84.0%, respectively). The interval between pregnancies did not differ significantly between the two groups. In the early cord-clamping group, the most common interval was 2 years (19, 46.3%), followed by 1 year (10, 24.4%). In the delayed cord-clamping group, a 2-year interval was also the most frequent (17, 34.0%), followed by 3 years (15, 30.0%). Similarly, gestational age was comparable between the two groups ($P > 0.05$). The most common gestational age was 38 weeks, accounting for 18 (36.0%) women in the early cord-clamping group and 26 (52.0%) in the delayed cord-clamping group, followed by 37 weeks in both groups (28.0% each). Regarding the indications for cesarean section, previous cesarean section was the most frequent indication in both groups, occurring in 27 women (54.0%) in the early cord-clamping group and 21 (42.0%) in the delayed cord-clamping group. Other indications included obstructed labour (14.0% vs. 6.0%), hypertension (8.0% vs. 6.0%), fetal distress/malpresentation (8.0% vs. 0.0%), gestational diabetes (4.0% vs. 4.0%), and breech presentation (4.0% vs. 10.0%) in the early and delayed cord-clamping groups, respectively. Less frequent indications included cervical tear, placental abruption, transverse lie, old primigravida, meconium, secondary infertility, and combinations involving previous cesarean section with diabetes, obstructed labour, fibroid, leaking, or cervical tear.

Table 2. Maternal obstetric characteristics and indications for cesarean section

Variable	Early cord clamping n (%)	Delayed cord clamping n (%)	P-value
Gravidity			0.017*
1–5	44 (88.0)	33 (66.0)	
>5	6 (12.0)	17 (34.0)	
Parity			NS
Nullipara	9 (18.0)	5 (10.0)	
1–5	41 (82.0)	42 (84.0)	
>5	0 (0.0)	3 (6.0)	
History of abortion			0.017*
Yes	6 (12.0)	17 (34.0)	
No	44 (88.0)	33 (66.0)	
Interval between pregnancies			NS
<1 year	0 (0.0)	1 (2.0)	
1 years	10 (24.4)	7 (14.0)	
2 years	19 (46.3)	17 (34.0)	
3 years	7 (7.11)	15 (30.0)	
4 years	5 (12.2)	4 (8.0)	
>4 years	0	1 (2.0)	
Gestational age			NS
36 weeks	1 (2.0)	0 (0.0)	
37 weeks	14 (28.0)	14 (28.0)	
38 weeks	18 (36.0)	26 (52.0)	
39 weeks	7 (14.0)	8 (16.0)	

40 weeks	7 (14.0)	2 (4.0)	
41 weeks	3 (6.0)	0 (0.0)	
Indication for C/S			
Previous C/S	27 (54.0)	21 (42.0)	
Obstructed labour	7 (14.0)	3 (6.0)	
Hypertension	4 (8.0)	3 (6.0)	
Fetal distress/malpresentation	4 (8.0)	0 (0.0)	
Gestational diabetes	2 (4.0)	2 (4.0)	
Breech presentation	2 (4.0)	5 (10.0)	
Cervical tear	1 (2.0)	1 (2.0)	
Placental abruption	1 (2.0)	0 (0.0)	
Transverse lie	1 (2.0)	1 (2.0)	
Old primigravida	1 (2.0)	1 (2.0)	
Meconium	0 (0.0)	1 (2.0)	
Secondary infertility	0 (0.0)	1 (2.0)	
Previous C/S + diabetes	0 (0.0)	3 (6.0)	
Previous C/S + obstructed labour	0 (0.0)	4 (8.0)	
Previous C/S + fibroid	0 (0.0)	1 (2.0)	
Previous C/S + leaking	0 (0.0)	2 (4.0)	
Previous C/S + cervical tear	0 (0.0)	1 (2.0)	

(Table 3) presents maternal complications and baseline neonatal characteristics according to cord-clamping group. No statistically significant differences were observed between the early and delayed cord-clamping groups for any of the assessed maternal or neonatal baseline characteristics ($P > 0.05$). Regarding maternal complications, postpartum hemorrhage occurred in 5 women (10.0%) in the early cord-clamping group compared with 4 women (8.0%) in the delayed cord-clamping group, with no statistically significant difference. Blood transfusion was required in 6 women (12.0%) in the early cord-clamping group and 2 women (4.0%) in the delayed cord-clamping group; this difference was also not statistically significant. The mean birth weight was 3.3 ± 0.43 kg among neonates in the early cord-clamping group and 3.2 ± 0.43 kg among those in the delayed cord-clamping group, with no significant difference between the groups. Most neonates had a birth weight of 2.5–4 kg, accounting for 48 (96.0%) in the early cord-clamping group and 47 (94.0%) in the delayed cord-clamping group. Birth weight below 2.5 kg was observed in 3 neonates (6.0%) in the delayed cord-clamping group and none in the early cord-clamping group, whereas birth weight above 4 kg occurred in 2 neonates (4.0%) in the early cord-clamping group and none in the delayed cord-clamping group. Regarding neonatal sex, males predominated in both groups, comprising 26 (52.0%) neonates in the early cord-clamping group and 31 (62.0%) in the delayed cord-clamping group. Female neonates accounted for 24 (48.0%) and 19 (38.0%), respectively. This difference was not statistically significant.

Table 3. Maternal complications and neonatal baseline characteristics

Variable	Early cord clamping n (%) / Mean $\pm$ SD	Delayed cord clamping n (%) / Mean $\pm$ SD	P-value
Maternal complications			
Postpartum hemorrhage	5 (10.0)	4 (8.0)	NS
Blood transfusion	6 (12.0)	2 (4.0)	NS
Birth weight (kg)	3.3 ± 0.43	3.2 ± 0.43	NS
<2.5 kg	0 (0.0)	3 (6.0)	
2.5–4 kg	48 (96.0)	47 (94.0)	
>4 kg	2 (4.0)	0 (0.0)	
Sex			NS
Male	26 (52.0)	31 (62.0)	
Female	24 (48.0)	19 (38.0)	

(Table 4) compares Apgar scores and neonatal clinical outcomes between the early and delayed cord-clamping groups. A statistically significant difference was observed in the Apgar score at 1 minute ($P = 0.022$). In the early cord-clamping group, Apgar scores of 8 and 9 were the most frequent, each occurring in 19 neonates (38.0%), whereas in the delayed cord-clamping group, an Apgar score of 9 was predominant, occurring in 29 neonates (58.0%). An Apgar score of 10 was recorded in 4 neonates (8.0%) in the delayed cord-clamping group, compared with none in the early cord-clamping group. A highly

statistically significant difference was observed in the Apgar score at 2 minutes ($P < 0.001$). In the early cord-clamping group, scores of 8 and 9 were each recorded in 19 neonates (38.0%), while in the delayed cord-clamping group, a score of 9 was most common, occurring in 35 neonates (70.0%). Furthermore, an Apgar score of 10 was observed in 7 neonates (14.0%) in the delayed cord-clamping group compared with only 2 (4.0%) in the early cord-clamping group. At 5 minutes, the majority of neonates in both groups had an Apgar score of 10. This was observed in 32 neonates (64.0%) in the early cord-clamping group and 38 (76.0%) in the delayed cord-clamping group. Apgar scores of 9 were recorded in 18 (36.0%) and 10 (20.0%) neonates, respectively, while a score of 8 occurred in 2 (4.0%) neonates in the delayed cord-clamping group and none in the early cord-clamping group. The difference in 5-minute Apgar scores was not statistically significant ($P = 0.091$).

Regarding neonatal clinical outcomes, respiratory distress occurred in 12 neonates (24.0%) in the early cord-clamping group compared with 4 (8.0%) in the delayed cord-clamping group; however, this difference was not statistically significant. The need for neonatal resuscitation was reported in 1 neonate (2.0%) in the early cord-clamping group and none in the delayed cord-clamping group, with no statistically significant difference. No cases of septicemia, jaundice, phototherapy requirement, or fetal injury were reported in either group. NICU admission occurred in 4 neonates (8.0%) in the early cord-clamping group compared with none in the delayed cord-clamping group; however, no P-value was reported for this outcome.

Table 4. Apgar scores and neonatal clinical outcomes according to cord-clamping group

Variable	Early cord clamping n (%)	Delayed cord clamping n (%)	P-value
Apgar score at 1 minute			0.022*
6	1 (2.0)	0 (0.0)	
7	11 (22.0)	4 (8.0)	
8	19 (38.0)	13 (26.0)	
9	19 (38.0)	29 (58.0)	
10	0 (0.0)	4 (8.0)	
Apgar score at 2 minutes			<0.001*
6	1 (2.0)	0 (0.0)	
7	9 (18.0)	3 (6.0)	
8	19 (38.0)	5 (10.0)	
9	19 (38.0)	35 (70.0)	
10	2 (4.0)	7 (14.0)	
Apgar score at 5 minutes			0.091
8	0 (0.0)	2 (4.0)	
9	18 (36.0)	10 (20.0)	
10	32 (64.0)	38 (76.0)	
Respiratory distress	12 (24.0)	4 (8.0)	NS
Need for resuscitation	1 (2.0)	0 (0.0)	NS
Septicemia	0 (0.0)	0 (0.0)	
Jaundice	0 (0.0)	0 (0.0)	
Phototherapy	0 (0.0)	0 (0.0)	
Fetal injury	0 (0.0)	0 (0.0)	
NICU admission	4 (8.0)	0 (0.0)	

(Table 5) compares neonatal hematological and biochemical parameters between the early and delayed cord-clamping groups at birth and 24 hours after birth. At birth, the mean hemoglobin level was significantly higher in neonates who underwent delayed cord clamping compared with those who underwent early cord clamping (16.9 ± 2.0 vs. 15.1 ± 1.9 g/dL, respectively; $P < 0.0001$). Similarly, the mean hematocrit was significantly higher in the delayed cord-clamping group ($45.9 \pm 7.5\%$) than in the early cord-clamping group ($41.5 \pm 5.5\%$; $P = 0.001$). After 24 hours, the mean hemoglobin level remained significantly higher among neonates in the delayed cord-clamping group compared with the early cord-clamping group (17.7 ± 1.9 vs. 15.5 ± 1.6 g/dL, respectively; $P < 0.0001$). The mean hematocrit was also significantly higher in the delayed cord-clamping group ($48.8 \pm 9.0\%$ vs. $44.2 \pm 8.9\%$; $P = 0.014$). No statistically significant difference was observed in mean corpuscular volume (MCV) between the two groups either at birth (99.0 ± 7.5 vs. 97.9 ± 7.6 fL; $P = 0.468$) or at 24 hours (96.9 ± 11.4 vs. 98.9 ± 12.0 fL; $P = 0.395$).

Regarding serum ferritin, there was no significant difference between the groups at birth. Mean ferritin levels were 149.5 ± 81.5 ng/mL in the early cord-clamping group and 149.6 ± 76.5 ng/mL in the delayed cord-clamping group ($P = 0.207$). However, at 24 hours, serum ferritin was significantly higher in the delayed cord-clamping group, with mean values of 251.9 ± 172.8 ng/mL compared with 180.3 ± 74.9 ng/mL in the early cord-clamping group ($P = 0.008$). For total bilirubin, no statistically significant difference was found between the groups either at birth or after 24 hours. At birth, mean bilirubin

levels were 1.9 ± 0.89 mg/dL in the early cord-clamping group and 1.7 ± 0.56 mg/dL in the delayed cord-clamping group ($P = 0.182$). After 24 hours, the corresponding values were 2.1 ± 2.0 and 2.7 ± 1.1 mg/dL, respectively ($P = 0.373$).

Table 5. Comparison of neonatal hematological and biochemical parameters at birth and after 24 hours

Parameter	Time	Early cord clamping Mean $\pm$ SD	Delayed cord clamping Mean $\pm$ SD	P-value
Hemoglobin (g/dL)	Birth	15.1 ± 1.9	16.9 ± 2.0	<0.0001
	24 h	15.5 ± 1.6	17.7 ± 1.9	<0.0001
Hematocrit (%)	Birth	41.5 ± 5.5	45.9 ± 7.5	0.001
	24 h	44.2 ± 8.9	48.8 ± 9.0	0.014
MCV (fL)	Birth	97.9 ± 7.6	99.0 ± 7.5	0.468
	24 h	98.9 ± 12.0	96.9 ± 11.4	0.395
Serum ferritin (ng/mL)	Birth	149.5 ± 81.5	149.6 ± 76.5	0.207
	24 h	180.3 ± 74.9	251.9 ± 172.8	0.008
Total bilirubin (mg/dL)	Birth	1.9 ± 0.89	1.7 ± 0.56	0.182
	24 h	2.1 ± 2.0	2.7 ± 1.1	0.373

Discussion

A total of 100 full-term neonates were included in the study, with 50 newborns assigned to the early cord-clamping group (≤ 1 minute) and 50 to the delayed cord-clamping group (> 1 minute). There was no statistically significant difference in mean maternal age between the two groups, and the distribution of mothers across different age categories was also comparable. This finding is consistent with previous research reporting no significant difference in maternal age between early- and delayed-clamping groups [9]. The majority of participants were Libyan, accounting for 90% of mothers in the early-clamping group and 94% in the delayed-clamping group. Most participants were residents of Ejdabia, representing 80% of the early-clamping group and 88% of the delayed-clamping group, while the remainder came from surrounding areas. Regarding educational attainment, 20% of mothers in the early-clamping group had primary education, 36% had secondary education, and 44% had university-level education.

In the delayed-clamping group, 4% had primary education, 30% had secondary education, and 66% had university-level education. The difference in maternal educational level between the two groups was statistically significant ($p = 0.020$). More than half of the mothers were housewives, accounting for 68% of the early-clamping group and 54% of the delayed-clamping group. Maternal hypertension was reported in 10% of mothers in each group. Diabetes mellitus was present in 4% of the early-clamping group and 12% of the delayed-clamping group, while asthma was reported in 2% of the early-clamping group. With respect to previous surgical history, cholecystectomy was reported in 8% of mothers in the early-clamping group and 6% in the delayed-clamping group. Appendectomy was reported in 4% and 2%, respectively, while open-heart surgery was reported in 2% of mothers in the early-clamping group. No previous surgical history was reported in 34% of the early group and 38% of the delayed group. Overall, the difference in surgical history between the two groups was not statistically significant ($p = 0.813$). There was no statistically significant difference in the mean number of pregnancies between the two groups ($p = 0.322$); however, a statistically significant difference was observed in the distribution of gravidity categories ($p = 0.017$). In the early-clamping group, 88% of mothers had 1–5 pregnancies and 12% had more than five, compared with 66% and 34%, respectively, in the delayed-clamping group. This finding differs from previous research, which reported no significant difference in gravidity between the groups ($p = 0.64$) [9].

Nulliparous women represented 18% of the early-clamping group and 10% of the delayed-clamping group. Parity of 1–5 was observed in 82% and 84%, respectively, while parity greater than five was not recorded in the early-clamping group but was present in 6% of the delayed-clamping group. Despite these differences, the overall difference was not statistically significant ($p = 0.387$). Similarly, previous research found no significant difference in parity between early- and delayed-clamping groups ($p = 0.54$), with nulliparity reported in 45% and 39.1%, respectively, and multiparity in 54% and 60.9%, respectively [18]. A history of abortion was reported in 12% of mothers in the early-clamping group compared with 34% in the delayed-clamping group, representing a statistically significant difference ($p = 0.017$). In contrast, there was no statistically significant difference between the groups regarding the interval between pregnancies ($p = 0.0518$). Gestational age at delivery showed a similar distribution in both groups, with no statistically significant difference ($p = 0.099$). The mean gestational age was 38.3 ± 1.2 weeks in the early-clamping group and 38.0 ± 0.78 weeks in the delayed-clamping group, with no significant difference between the means ($p = 0.142$). Comparable findings have been reported previously, including one study in which the mean gestational age was 34 weeks in both groups [1], while another reported no significant difference between groups ($p = 0.25$) [9].

The most frequent indication for cesarean section was previous cesarean delivery, accounting for 54% of cases in the early-clamping group and 42% in the delayed-clamping group. Obstructed labor accounted for 14% and 6%, respectively, while breech presentation represented 4% of early-clamping and 10% of delayed-clamping cases. Other indications occurred at relatively low frequencies. Postpartum hemorrhage occurred in 10% of mothers in the early-clamping group and 8% in the delayed-clamping group. Blood transfusion was required in 12% of the early-clamping group compared with 4% of the delayed-clamping group. Early cord clamping was historically recommended as a measure to reduce postpartum

hemorrhage and maternal blood transfusion requirements [19]. However, several studies have found no association between delayed cord clamping in term or preterm infants and maternal postpartum hemorrhage, maternal blood loss, or the need for blood transfusion [19–24].

Regarding neonatal birth weight, no infant in the early-clamping group weighed less than 2.5 kg, compared with 6% in the delayed-clamping group. Birth weight between 2.5 and 4 kg was recorded in 96% of the early-clamping group and 94% of the delayed-clamping group, while birth weight above 4 kg occurred in 4% of the early-clamping group. Comparison of mean birth weight showed no statistically significant difference between the groups ($p = 0.249$). Similarly, previous research reported a birth-weight range of 2.65–4.0 kg in both groups, with mean weights of 3.15 ± 0.28 kg in the early-clamping group and 3.13 ± 0.33 kg in the delayed-clamping group, without a significant difference ($p = 0.753$) [1]. Male neonates constituted 52% of the early-clamping group and 62% of the delayed-clamping group. However, the difference in neonatal sex distribution was not statistically significant ($p = 0.419$). Similar findings were reported previously, with males representing 52% of the early-clamping group and 42% of the delayed-clamping group, and no statistically significant difference between groups ($p = 0.218$) [1]. Apgar scores at one minute were higher among neonates in the delayed-clamping group. No neonate in the early-clamping group achieved an Apgar score of 10, whereas 8% of neonates in the delayed-clamping group did. The difference was statistically significant ($p = 0.022$). This finding contrasts with previous research that found no significant difference in one-minute Apgar scores between the groups ($p = 0.32$) [9]. At two minutes, the difference in Apgar scores was highly statistically significant ($p = 0.0001$), with higher scores observed in the delayed-clamping group. By five minutes, however, Apgar scores were comparable between the groups, with no statistically significant difference ($p = 0.091$). This finding agrees with previous research reporting no significant difference in five-minute Apgar scores ($p = 1.00$) [9].

Regarding neonatal outcomes, respiratory distress occurred in 24% of neonates in the early-clamping group compared with 8% in the delayed-clamping group, although this difference was not statistically significant. Resuscitation was required in 2% of neonates in the early-clamping group, while admission to the neonatal intensive care unit occurred in 8% of neonates in this group. A marked difference was observed in neonatal hemoglobin concentration at birth. Hemoglobin levels of 11–17.3 g/dL were observed in 86% of neonates in the early-clamping group compared with 42% in the delayed-clamping group, whereas levels above 17.3 g/dL were observed in 16% and 58%, respectively. This difference was highly statistically significant ($p = 0.0001$), indicating higher hemoglobin concentrations among neonates exposed to delayed cord clamping. In contrast, previous research reported mean hemoglobin levels of 16.21 ± 1.61 g/dL and 16.54 ± 1.58 g/dL in the early- and delayed-clamping groups, respectively, with no significant difference ($p = 0.308$) [1]. At 24 hours after birth, hemoglobin levels of 11–17.3 g/dL were recorded in 16% of neonates in the early-clamping group and 50% in the delayed-clamping group, while levels above 17.3 g/dL were found in 84% and 50%, respectively. The difference remained highly statistically significant ($p = 0.0001$). This finding is consistent with previous research in which neonatal hemoglobin was significantly higher following delayed cord clamping than immediate clamping, with mean concentrations of 18.1 g/dL (95% CI, 17.4–18.8) and 16.4 g/dL (95% CI, 15.9–17.0), respectively; the mean difference was 1.67 g/dL (95% CI, 0.75–2.59; $p < 0.001$) [25]. Conversely, another study found no significant difference in mean neonatal hemoglobin between the two groups ($p = 0.622$) [2]. The distribution of neonatal hematocrit at birth did not differ significantly between the groups ($p = 0.124$). Hematocrit below 35.4% was found in 16% of neonates in the early-clamping group and 14% in the delayed-clamping group. Levels between 35.4% and 56.5% were observed in 84% and 78%, respectively, while hematocrit above 56.5% was found in 8% of neonates in the delayed-clamping group and none in the early-clamping group. These findings are consistent with previous research in which mean hematocrit was $50.18 \pm 4.66\%$ in the early-clamping group and $51.16 \pm 5.09\%$ in the delayed-clamping group, with no statistically significant difference ($p = 0.318$) [1].

Similarly, other investigators reported that delayed cord clamping did not produce a significant difference in neonatal hematocrit levels [26]. At 24 hours, hematocrit below 35.4% was observed in 8% of neonates in the early-clamping group and 2% in the delayed-clamping group. Levels between 35.4% and 56.5% were found in 90% and 92%, respectively, while levels above 56.5% were recorded in 2% and 6%. The difference remained statistically nonsignificant ($p = 0.245$). This is comparable to previous findings showing no significant difference in hematocrit measured 24–48 hours after birth between early- and delayed-clamping groups, with reported mean values of $57.47 \pm 8.65\%$ and $59.54 \pm 7.67\%$, respectively [9]. Mean corpuscular volume (MCV) at birth was below 90.4 fL in 2% of neonates in the early-clamping group and 6% in the delayed-clamping group, while 98% and 94%, respectively, had MCV values between 90.4 and 128 fL. The difference was not statistically significant ($p = 0.610$). Similarly, previous research reported mean MCV values of 112.89 ± 6.74 fL in the early-clamping group and 111.36 ± 8.09 fL in the delayed-clamping group, with no significant difference ($p = 0.306$) [1]. At 24 hours, MCV below 90.4 fL was observed in 8% of the early-clamping group and 12% of the delayed-clamping group, while values between 90.4 and 128 fL were observed in 92% and 88%, respectively.

Again, no statistically significant difference was found between the groups ($p = 0.739$). Serum ferritin levels at birth also showed no statistically significant difference between the groups ($p = 0.908$). Ferritin below 25 ng/mL was observed in 4% of neonates in each group, while levels between 25 and 200 ng/mL were observed in 68% of the early-clamping group and 64% of the delayed-clamping group. Levels above 200 ng/mL were recorded in 32% of the early-clamping group and 28% of the delayed-clamping group. Similarly, previous research found no significant difference in mean ferritin levels, reporting values of 1.44 ± 0.75 in the early group and 1.26 ± 0.65 in the delayed group ($p = 0.202$) [1]. In contrast, another study reported significantly higher ferritin concentrations in infants who underwent delayed cord clamping [3]. At 24 hours, ferritin below 25 ng/mL was present in 6% of neonates in the early-clamping group and 2% in the delayed-clamping group. Levels between 25 and 200 ng/mL were recorded in 36% and 54%, respectively, while levels above 200 ng/mL were observed in

40% and 62%. Although a higher proportion of neonates in the delayed-clamping group had ferritin levels above 200 ng/mL, the overall difference did not reach statistical significance ($p = 0.075$). Total bilirubin concentrations at birth were also comparable between the two groups. Levels of 0.1–1.2 mg/dL were recorded in 18% of neonates in the early-clamping group and 16% in the delayed-clamping group, whereas levels above 1.2 mg/dL occurred in 82% and 84%, respectively ($p = 1.000$). At 24 hours, bilirubin levels of 0.1–1.2 mg/dL were observed in 18% of the early-clamping group and 10% of the delayed-clamping group, while levels above 1.2 mg/dL were recorded in 82% and 90%, respectively. This difference was not statistically significant ($p = 0.387$). These findings are consistent with previous studies reporting no significant difference in total bilirubin between early- and delayed-clamping groups.

One study reported mean bilirubin values of 1.44 ± 0.75 and 1.26 ± 0.65 , respectively ($p = 0.202$) [1], while another found no significant difference in total serum bilirubin levels ($p = 0.359$) [16]. When the mean neonatal laboratory parameters at birth were directly compared, hemoglobin concentration was significantly higher in the delayed-clamping group than in the early-clamping group ($p = 0.0001$). No significant difference was observed in MCV ($p = 0.468$). Hematocrit was significantly higher in the delayed-clamping group ($p = 0.001$), whereas serum ferritin ($p = 0.207$) and bilirubin ($p = 0.182$) did not differ significantly between the groups. A similar pattern was observed at 24 hours. Mean hemoglobin concentration was significantly higher in the delayed-clamping group ($p = 0.0001$), whereas MCV remained statistically comparable between the groups ($p = 0.395$). Mean hematocrit was significantly higher in the delayed-clamping group ($p = 0.014$). In addition, mean serum ferritin was significantly higher following delayed cord clamping, measuring 251.9 ± 172.8 compared with 180.3 ± 74.9 in the early-clamping group ($p = 0.008$). In contrast, mean bilirubin levels remained comparable between the groups ($p = 0.373$). Overall, these findings indicate that delayed cord clamping was associated with improved neonatal hematological indices, particularly higher hemoglobin, hematocrit, and ferritin concentrations, without a significant increase in bilirubin levels. This pattern is consistent with previous evidence showing that delayed cord clamping is associated with increased neonatal hematocrit, hemoglobin, and ferritin concentrations during the early neonatal period [3]. Other research has similarly demonstrated highly significant differences between early- and delayed-clamping groups in neonatal hemoglobin, hematocrit, and ferritin levels ($p < 0.001$), while finding no significant difference in total bilirubin levels after four hours ($p > 0.05$) [4].

Conclusion

Delayed cord clamping was associated with significantly improved neonatal hematological outcomes in full-term infants delivered by cesarean section, as evidenced by higher hemoglobin and hematocrit levels at birth and at 24 hours, and higher serum ferritin levels at 24 hours. No significant differences were observed in MCV or total bilirubin, and delayed cord clamping was not associated with increased postpartum hemorrhage, blood transfusion, respiratory distress, or need for neonatal resuscitation. Therefore, delayed cord clamping for more than one minute can be considered a safe and beneficial practice for stable term neonates delivered by cesarean section. It is recommended that delayed cord clamping be incorporated into routine obstetric practice when maternal and neonatal conditions permit, with appropriate training of healthcare providers, while larger multicenter studies with longer follow-up are recommended to evaluate its long-term effects on neonatal iron status, anemia, growth, and neurodevelopment.

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Conflicts of Interest

The authors declare no conflicts of interest.

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