Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Delayed umbilical cord clamping and early maternal haematological outcomes: a calendar-time-adjusted cohort of 4,632 deliveries

Gülşah Aynaoğlu Yıldız
Ankara University
Goksu Goc
goksu.goc@gmail.com
American Hospital Kosovo
Hasan Süt
Ankara University
Batuhan Turgay
Ankara University
Bircan Yıldırım Baydemir
Ankara University
Engin Öztürk
Ankara University
Cem Somer Atabekoğlu
Ankara University

Research Article

Keywords: Delayed cord clamping, Postpartum anaemia, Postpartum haemorrhage, Propensity score, Inverse probability weighting, Maternal outcomes, Observational cohort study

Posted Date: August 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10450694/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background.

Delayed umbilical cord clamping (DCC) is recommended for neonatal benefit, but maternal haematological safety concerns persist and may slow uptake. Because DCC is adopted progressively, calendar time confounds implementation-era cohorts. We estimated the association between DCC ≥ 60 seconds and early postpartum maternal haematological outcomes with explicit adjustment for calendar-time confounding.

Methods.

Single-centre retrospective cohort of 4,644 consecutive deliveries at ≥ 22 weeks' gestation between 6 June 2022 and 31 December 2024 (4,632 with valid delivery dates for the calendar-adjusted analysis) at a university obstetric department in Ankara, Turkey. The exposure was DCC ≥ 60 seconds versus immediate or 30-second clamping. Calendar time was modelled as a natural cubic spline. The primary analysis used stabilised inverse-probability-of-treatment weighting (IPTW); covariate-adjusted modified Poisson regression, overlap weighting and 1:1 propensity-score matching were complementary analyses. Firth-penalised logistic regression handled the sparse transfusion outcome, and E-values addressed unmeasured confounding. The primary outcome was postpartum anaemia (venous haemoglobin < 10 g/dL at 6 hours).

Results.

1,889 (40.8%) episodes received DCC; adoption rose from 10.2% in 2022 to 62.3% in 2024. On the primary analysis, DCC was not associated with postpartum anaemia (stabilised IPTW risk ratio 1.01, 95% CI 0.88–1.16; covariate-adjusted 1.00, 0.91–1.10; overlap 0.99, 0.87–1.13), postpartum haemorrhage (1.11, 0.77–1.59), haemoglobin drop ≥ 2 g/dL (0.98, 0.81–1.18) or blood transfusion (0.74, 0.24–2.25). A propensity-score-matched sensitivity analysis that did not achieve calendar-time balance (maximum standardised mean difference 0.18, versus 0.05 under IPTW) gave concordant, non-significant estimates (anaemia 0.93, 0.82–1.07). An exploratory delivery-mode interaction was observed (interaction ratio 0.78, 95% CI 0.65–0.93; p = 0.007): vaginal delivery 1.19 (1.02–1.38); caesarean delivery 0.91 (0.81–1.03).

Conclusions.

After calendar-time-adjusted multimethod analysis, DCC ≥ 60 seconds was not associated with worse maternal haematological outcomes overall. The delivery-mode divergence is hypothesis-generating and warrants prospective evaluation before any change in practice.

Trial registration.

Not applicable (observational cohort study).

Background

Postpartum haemorrhage remains a leading direct cause of preventable maternal morbidity and mortality, and antenatal anaemia is one of its most important modifiable risk factors [1, 2]. Delayed umbilical cord clamping (DCC), commonly defined as clamping at or after 60 seconds following birth, improves neonatal circulatory transition and iron endowment and is now embedded in major contemporary obstetric guidance and evidence syntheses [3–5]. The 2025 World Health Organization consolidated guidelines on the prevention, diagnosis and treatment of postpartum haemorrhage further reinforce maternal anaemia as a central modifiable factor and call for implementation evidence on third-stage practices [2].

Despite robust neonatal benefit, concern persists that prolonged placental transfusion may delay uterine retraction or interact with the timing of uterotonic administration, thereby increasing the risk of postpartum anaemia, postpartum haemorrhage (PPH) or transfusion [3, 6]. The randomised evidence base for maternal outcomes is limited and heterogeneous: a foundational trial reported no excess maternal blood loss with DCC of three minutes [6], a subsequent randomised trial in term caesarean delivery similarly found no increase in maternal blood loss with DCC of 60 seconds [7], and a 2025 meta-analysis at caesarean delivery reported no increase in estimated blood loss, PPH, transfusion, uterotonic use or surgical time [8]. Recent paired individual-participant-data meta-analyses [9, 10] have advanced understanding for preterm infants but did not focus on maternal endpoints. Implementation-era observational cohorts therefore remain valuable for triangulating maternal safety, but they introduce a methodological challenge that is rarely addressed transparently.

When DCC is implemented progressively, women who receive DCC may differ systematically from those who receive earlier clamping, and these differences can co-vary with secular changes in obstetric staffing, uterotonic protocols, awareness of haemorrhage and clinical documentation [11, 12]. Calendar-time confounding is therefore a central threat to inference. We aimed to estimate the association between guideline-concordant DCC (≥ 60 s) and early postpartum maternal haematological outcomes versus immediate or 30-second clamping in a single university centre, using complementary regression and propensity-score approaches with explicit modelling of calendar time, and to examine whether estimates varied by delivery mode.

Methods

Study design and population

This was a single-centre retrospective cohort study of consecutive delivery episodes at a university obstetrics and gynaecology department between 6 June 2022 and 31 December 2024. The study is reported in accordance with the STROBE statement for cohort studies [13]. Eligible records were deliveries at ≥ 22 weeks' gestation, including singleton and multiple pregnancies. From an initial register of 5,073 delivery records, we excluded 7 triplet pregnancies, 354 deliveries with intrapartum fetal distress, 11 with major fetal anomalies, 30 with placental anomalies and 33 with maternal haematological disorders, leaving 4,644 episodes for analysis (some exclusions overlapped). Twelve records had missing (blank) delivery dates and were excluded from calendar-adjusted models. One further record carried an implausible delivery date recorded in 2002, more than 19 years before the study window; this was judged a year-field data-entry error, corrected to the intended 2022 admission, and retained. This left 4,632 episodes for the primary adjusted analysis. The flow of records is summarised in Fig. 1. The exposure and 6-hour postpartum haemoglobin were complete; blood transfusion status was missing for two records.

Exposure

The primary exposure was guideline-concordant DCC, defined as cord clamping at ≥ 60 seconds after delivery, compared with immediate or 30-second clamping. Recorded categories were 0 s, 30 s, 60 s and 120 s; these were used in dose–response sensitivity analyses. Cord-clamping timing was determined by the attending obstetrician according to local practice, and routine documentation took place in the electronic delivery record.

Outcomes

The primary outcome was postpartum anaemia, defined as venous haemoglobin < 10 g/dL at the 6-hour postpartum measurement. Secondary outcomes were postpartum anaemia at the < 11 g/dL threshold; haemoglobin drop ≥ 2 g/dL from pre-delivery to 6 hours postpartum; clinically recorded PPH; blood transfusion during the delivery admission; continuous 6-hour postpartum haemoglobin; and continuous haemoglobin drop. PPH was analysed as recorded in the clinical dataset; quantitative measured blood-loss values were not consistently available, and the absence of standardised quantitative blood-loss measurement is acknowledged as a limitation.

Data sources and measurement

Data were extracted electronically from the hospital electronic delivery record and the laboratory information system. Cord-clamping time was documented by the attending obstetrician or midwife as a categorical field (0, 30, 60 or 120 seconds) at the time of delivery as part of routine care; because it was captured categorically in the routine record, whether the interval was stopwatch-measured or clinically estimated could not be verified retrospectively, and this is acknowledged as a limitation. The primary haematological outcome used the first routine venous haemoglobin obtained at approximately 6 hours

postpartum; the 6-hour time point captures the early postpartum nadir before haematological recovery, and the < 10 g/dL threshold reflects a widely used definition of clinically significant early postpartum anaemia. Clinically recorded postpartum haemorrhage was analysed as documented in the delivery record (conventionally, estimated blood loss ≥ 500 mL after vaginal and ≥ 1000 mL after caesarean delivery); standardised quantitative blood-loss measurement was not consistently available, which is acknowledged as a limitation. Records and outcomes were extracted electronically and subjected to automated range and consistency checks; outcomes were not additionally adjudicated by manual chart review.

Covariates and propensity-score model

Covariates were selected using clinical knowledge and directed-acyclic-graph reasoning, prioritising baseline maternal characteristics that plausibly affect both exposure (DCC adoption decisions and timing) and outcome (postpartum haemoglobin trajectory). The retained covariates were pre-delivery haemoglobin, body mass index, parity, delivery mode, plurality, grand multiparity, iron use during pregnancy, intravenous ferric carboxymaltose use, any maternal comorbidity, any pregnancy complication, and calendar time modelled as a natural cubic spline with three degrees of freedom. Continuous covariates with possible non-linear effects (pre-delivery haemoglobin and body mass index) were also entered as natural cubic splines (df = 3) in the propensity model. Uterotonic agent was described in baseline tables because it was imbalanced, but it was not included as a primary confounder because timing relative to the exposure and outcome could not be established reliably and inclusion risked adjustment for a downstream variable.

Statistical analysis

Binary outcomes were analysed using modified Poisson regression with robust standard errors to estimate risk ratios (RRs) [14]; continuous outcomes used linear regression for mean differences. The primary analysis estimated the average treatment effect (ATE) of DCC ≥ 60 s versus immediate or 30-second clamping using stabilised inverse-probability-of-treatment weighting (IPTW), with weights truncated at the 1st and 99th percentiles. Two further balanced approaches were included as complementary analyses that, by design, target subtly different estimands: covariate-adjusted modified Poisson regression (a model-based adjusted association) and overlap weighting, which estimates the average treatment effect in the overlap population (ATO). We interpret these three estimates as complementary analyses in different target populations rather than as interchangeable estimates of a single effect; concordance across them strengthens a maternal-safety inference. IPTW and overlap-weighted outcome models used survey-weighted quasi-Poisson regression with a log link and sandwich-type robust standard errors. Separately, 1:1 nearest-neighbour propensity-score matching with a 0.2 SD caliper (average treatment effect in the treated, ATT; standard errors clustered by matched set) was performed as a sensitivity analysis; because matching did not achieve balance on calendar time

(maximum residual SMD 0.18), it is reported in Additional file 1 (Table S4) and is not used for primary inference.

The covariate-adjusted outcome models and the propensity-score model included pre-delivery haemoglobin, body mass index, parity, delivery mode, plurality, grand multiparity, iron use during pregnancy, intravenous ferric carboxymaltose use, any maternal comorbidity, any pregnancy complication, and calendar time; pre-delivery haemoglobin, body mass index and calendar time were modelled as natural cubic splines with three degrees of freedom in both model families, and the remaining covariates as linear terms or indicator contrasts. Covariate balance was assessed using standardised mean differences (SMDs), computed from the weights actually analysed (i.e. after truncation), with a target of < 0.10 both before and after weighting and matching. The propensity-score model, the covariate-balance diagnostics for each method, and the matched balance table with the maximum residual SMD are provided in Additional file 1. No formal a priori sample-size calculation was performed because the study included all eligible consecutive deliveries during the study period; the achieved sample provided reasonable precision for common outcomes, whereas rare outcomes (notably transfusion) remained imprecise.

A clinically motivated delivery-mode interaction was examined on a multiplicative scale with a product term and explored with mode-specific adjusted estimates; this interaction, and the plurality and pre-delivery-anaemia subgroups, were treated as exploratory. Sensitivity analyses comprised a four-level timing model, conventional logistic regression, and Firth-penalised logistic regression for the sparse transfusion outcome [15]. E-values were calculated for the primary IPTW estimate [16]; because the confidence interval crossed the null, the limit E-value was 1.00 by construction and was not interpreted as proof of robustness. Estimates are presented with 95% confidence intervals; p-values are reported where they aid interpretation of interaction tests [12]. Because the de-identified dataset did not contain a maternal identifier, repeat deliveries by the same woman could not be linked or accounted for (see Strengths and limitations). Analyses used R with the WeightIt, MatchIt, cobalt, survey, sandwich, logistf, EValue and splines packages. The full analysis script and de-identified analysis dataset are available as described under Availability of data and materials.

Use of large language models

Generative artificial-intelligence tools (large language models) were used to assist with language editing.

Ethics

The study was approved by the Ethics Committee of Ankara University School of Medicine (decision number 1741076; approval date 26 February 2025); informed consent was waived because the analysis used retrospective de-identified routine clinical data, in accordance with national regulations and the Declaration of Helsinki.

Patient and public involvement

Patients or the public were not directly involved in the design, conduct, reporting or dissemination plans of this study, which used retrospective de-identified routine clinical data. A plain-language summary of the findings is provided in the public reproducibility repository to support patient-facing communication.

Results

Study population and DCC adoption

The full cohort included 4,644 delivery episodes (Fig. 1): 2,751 immediate or 30-second clamping episodes and 1,893 DCC ≥ 60 s episodes. The calendar-adjusted analysis cohort comprised 4,632 episodes, including 2,743 immediate or 30-second and 1,889 DCC episodes. DCC adoption increased from 10.2% in 2022 to 40.3% in 2023 and 62.3% in 2024 (Fig. 5 and Additional file 1, Table S3).

Baseline characteristics and balance

Baseline characteristics by exposure group are shown in Table 1. Calendar time was the largest pre-adjustment imbalance (delivery-year SMD 1.008; delivery-date numeric SMD 1.005). Body mass index (SMD 0.126), plurality (SMD 0.129), intravenous ferric carboxymaltose use (SMD 0.102) and uterotonic agent (SMD 0.135) showed modest imbalance. After stabilised, truncated IPTW, all covariates met the SMD < 0.10 threshold; the largest residual SMD was 0.05 on a calendar-time spline term. Overlap weighting achieved near-exact balance across retained covariates. The Love plot is shown in Fig. 2; supplementary Love plots and balance tables are provided for IPTW and overlap weighting (Additional file 1, Figs. S1–S2). The IPTW effective sample size was 2,350.0 in the immediate or 30 s group and 1,113.3 in the DCC group (a reduction of about 41% from 1,889), reflecting reliance on the relatively small number of early-period DCC observations to inform the calendar-adjusted estimate. In contrast, 1:1 matching did not fully balance calendar time (maximum residual covariate SMD 0.18; the propensity-score distance and two calendar-time spline components had absolute SMDs above 0.10), and its balance table is provided in Additional file 1.

Table 1
Baseline characteristics by primary exposure (full cohort, n = 4,644).

Characteristic	Immediate/30 s (n = 2,751)	DCC ≥ 60 s (n = 1,893)	SMD
Pre-delivery haemoglobin, g/dL, mean (SD)	11.87 (1.28)	11.96 (1.19)	0.078
Body mass index, kg/m², mean (SD)	28.76 (4.61)	29.35 (4.77)	0.126
Parity, mean (SD)	0.93 (0.95)	0.94 (0.94)	0.007
Vaginal delivery, n (%)	1,296 (47.1)	963 (50.9)	0.075
Caesarean delivery, n (%)	1,455 (52.9)	930 (49.1)	—
Delivery year 2022, n (%)	1,175 (42.8)	135 (7.1)	1.008
Delivery year 2023, n (%)	855 (31.2)	578 (30.6)	—
Delivery year 2024, n (%)	713 (26.0)	1,176 (62.3)	—
Delivery date missing/invalid, n (%)	8 (0.3)	4 (0.2)	—
Multiple pregnancy, n (%)	113 (4.1)	36 (1.9)	0.129
Pre-delivery anaemia (Hb < 11 g/dL), n (%)	652 (23.7)	375 (19.8)	0.094
Iron use during pregnancy, n (%)	2,651 (96.4)	1,808 (95.5)	0.043
Intravenous ferric carboxymaltose, n (%)	29 (1.1)	45 (2.4)	0.102
Any maternal comorbidity, n (%)	569 (20.7)	345 (18.2)	0.062
Any pregnancy complication, n (%)	143 (5.2)	94 (5.0)	0.011
Uterotonic agent: carbetocin, n (%)	721 (26.2)	393 (20.8)	0.135
Uterotonic agent: oxytocin, n (%)	2,025 (73.6)	1,499 (79.2)	—
Uterotonic agent: unclear/needs verification, n (%)	5 (0.2)	1 (0.1)	—

Values are n (%) unless otherwise stated. Percentages for the delivery-year categories use the valid-date group denominators (2,743 immediate/30 s; 1,889 DCC); all other percentages use the full-cohort group totals (2,751 immediate/30 s; 1,893 DCC). The 12 episodes with a missing or invalid delivery date (8 immediate/30 s; 4 DCC) are shown as a separate category and were excluded from the calendar-adjusted analysis (n = 4,632). Uterotonic categories (including "unclear/needs verification") sum to the full-cohort group totals. Maternal age was unavailable in the analysis dataset and could not be included in descriptive or adjusted analyses. SMD, standardised mean difference; Hb, haemoglobin; SD, standard deviation; DCC, delayed cord clamping.

Primary outcome

In the adjusted analysis cohort, postpartum anaemia (Hb < 10 g/dL) occurred in 624 of 2,743 immediate or 30-second episodes (22.7%) and 390 of 1,889 DCC episodes (20.6%). The unadjusted RR in the full cohort was 0.91 (95% CI 0.81–1.01). After adjustment, the primary stabilised IPTW estimate showed no association (RR 1.01, 0.88–1.16), as did the covariate-adjusted (RR 1.00, 0.91–1.10) and overlap-weighted (RR 0.99, 0.87–1.13) analyses. A propensity-score-matched sensitivity analysis, which did not achieve calendar-time balance (maximum standardised mean difference 0.18 on a calendar-time spline term, compared with 0.05 under IPTW), gave a concordant, non-significant estimate (RR 0.93, 0.82–1.07; p = 0.323); because of this residual imbalance it is treated only as a cautious sensitivity analysis and is not used for primary inference (Additional file 1, Table S4; see Discussion). The three balanced methods are summarised in Fig. 3 and Table 2.

Table 2
Cross-method outcome estimates for delayed cord clamping ≥ 60 s versus immediate or 30-second clamping (calendar-adjusted analysis cohort, n = 4,632).

Outcome	Immediate/30 s	DCC ≥ 60 s	Covariate-adjusted	Stabilised IPTW (primary)	Overlap weighting
Postpartum anaemia, Hb < 10 g/dL	624/2,743 (22.7%)	390/1,889 (20.6%)	1.00 (0.91–1.10)	1.01 (0.88–1.16)	0.99 (0.87–1.13)
Postpartum anaemia, Hb < 11 g/dL	1,445/2,743 (52.7%)	957/1,889 (50.7%)	0.97 (0.93–1.02)	0.98 (0.91–1.04)	0.97 (0.91–1.03)
Haemoglobin drop ≥ 2 g/dL	329/2,743 (12.0%)	250/1,889 (13.2%)	0.89 (0.75–1.04)	0.98 (0.81–1.18)	0.89 (0.75–1.05)
Clinically recorded PPH	86/2,743 (3.1%)	82/1,889 (4.3%)	1.12 (0.81–1.53)	1.11 (0.77–1.59)	1.12 (0.80–1.58)
Blood transfusion	20/2,743 (0.7%)	8/1,887 (0.4%)	0.65 (0.27–1.58)	0.74 (0.24–2.25)	0.58 (0.24–1.43)
6-hour postpartum Hb, g/dL	—	—	0.01 (− 0.04 to 0.06)	0.00 (− 0.09 to 0.10)	0.02 (− 0.07 to 0.10)
Haemoglobin drop, g/dL	—	—	−0.01 (− 0.06 to 0.04)	−0.01 (− 0.07 to 0.05)	−0.02 (− 0.07 to 0.04)

Binary outcomes are risk ratios (RR) with 95% confidence intervals; continuous outcomes are mean differences (g/dL) with 95% confidence intervals. Observed counts are from the calendar-adjusted cohort except blood transfusion (two records missing). Stabilised IPTW is the primary analysis; the three approaches shown achieved covariate balance (all standardised mean differences < 0.10). A 1:1 propensity-score-matched sensitivity analysis, which did not achieve calendar-time balance, is reported separately (Additional file 1, Table S4). IPTW, inverse probability of treatment weighting; PPH, postpartum haemorrhage; Hb, haemoglobin; DCC, delayed cord clamping.

Secondary outcomes

DCC was not associated with postpartum anaemia using the Hb < 11 g/dL threshold, haemoglobin drop ≥ 2 g/dL (cross-method estimates in Fig. 3; subject-level distribution in Additional file 1, Fig. S3), continuous haemoglobin measures, PPH or blood transfusion after adjustment (Table 2). PPH was higher before adjustment (unadjusted RR 1.39, 95% CI 1.03–1.86) but the association attenuated after calendar-time and covariate adjustment (covariate-adjusted RR 1.12, 95% CI 0.81–1.53; primary IPTW RR 1.11, 95% CI 0.77–1.59). The transfusion outcome was sparse, with 28 events in the analysed cohort; Firth-penalised logistic regression yielded an odds ratio of 0.65 (95% CI 0.26–1.55).

Delivery-mode interaction

A delivery-mode product term suggested divergence in postpartum anaemia estimates (interaction ratio 0.78, 95% CI 0.65–0.93; p = 0.007). In delivery-mode-specific adjusted models the vaginal-delivery estimate was RR 1.19 (95% CI 1.02–1.38; p = 0.029), whereas the caesarean-delivery estimate was RR 0.91 (95% CI 0.81–1.03; p = 0.131) (Table 3, Fig. 4). Similar divergence was observed for clinically recorded PPH (interaction ratio 0.44, 95% CI 0.23–0.83; p = 0.012) and continuous haemoglobin drop (interaction difference − 0.15 g/dL, 95% CI − 0.24 to − 0.07; p < 0.001). The delivery-mode interaction was the primary interaction of interest; the plurality and pre-delivery-anaemia rows in Table 3 present within-subgroup adjusted associations from exploratory analyses and should not be interpreted as tests of heterogeneity.

Table 3
Delivery-mode and subgroup adjusted estimates for the primary outcome (postpartum anaemia, Hb < 10 g/dL).

Subgroup or interaction	N	Events	Estimate (95% CI)	P-value
Vaginal delivery	2,253	384	1.19 (1.02–1.38)	0.029
Caesarean delivery	2,379	630	0.91 (0.81–1.03)	0.131
Singleton pregnancy	4,484	967	1.01 (0.92–1.11)	0.850
Multiple pregnancy	148	47	0.79 (0.48–1.30)	0.351
Pre-delivery anaemia	1,027	673	0.97 (0.89–1.06)	0.542
No pre-delivery anaemia	3,605	341	1.02 (0.82–1.26)	0.879
Postpartum anaemia interaction ratio	4,632	1,014	0.78 (0.65–0.93)	0.007
PPH interaction ratio	4,632	168	0.44 (0.23–0.83)	0.012
Hb drop interaction difference, g/dL	4,632	—	−0.15 (− 0.24 to − 0.07)	< 0.001

Subgroup rows are adjusted risk ratios (RR) with 95% confidence intervals. Interaction-ratio rows are product-term estimates comparing the DCC effect in caesarean versus vaginal delivery; for haemoglobin drop the estimate is a mean-difference interaction. DCC, delayed cord clamping; PPH, postpartum haemorrhage; Hb, haemoglobin.

Sensitivity analyses

Four-level timing analyses did not show a monotonic dose–response for postpartum anaemia (Additional file 1, Fig. S4). Compared with immediate clamping, the RRs were 0.88 (95% CI 0.77–0.99) for 30 seconds, 0.92 (0.80–1.05) for 60 seconds and 0.89 (0.73–1.09) for 120 seconds. The point E-value for the IPTW estimate was 1.13 and the limit E-value was 1.00, reflecting the near-null estimate and confidence interval crossing the null rather than evidence of robustness against unmeasured confounding (Additional file 1, Table S2).

Discussion

Main findings

In this single-centre, calendar-time-adjusted cohort of 4,632 delivery episodes, DCC ≥ 60 s was not associated with worse maternal haematological outcomes overall. The primary anaemia estimate was close to the null across the primary stabilised IPTW analysis and the covariate-adjusted and overlap-weighted complementary analyses, and secondary outcomes did not indicate increased risk of PPH, haemoglobin drop ≥ 2 g/dL or transfusion after adjustment.

The analysis also illustrates the importance of explicitly modelling calendar time. DCC adoption rose sharply over the study period; unadjusted PPH estimates were materially attenuated after modelling calendar time and baseline covariates, supporting calendar time as a major source of confounding rather than a direct PPH effect of DCC. The behaviour of the propensity-score-matched analysis reinforces this point. Stabilised IPTW and overlap weighting, which balanced calendar time almost completely (maximum residual SMD 0.05), returned null estimates, and 1:1 matching, despite leaving appreciable residual calendar-time imbalance (maximum residual SMD 0.18), gave a concordant, non-significant anaemia estimate (RR 0.93, 0.82–1.07). Because matching discards unmatched records (2,934 of 4,632 episodes were retained) and, here, did not fully balance calendar time, the matched estimate is the least reliable of the four approaches and is sensitive to small changes in the matched set; we therefore treat it only as a cautious sensitivity analysis and base inference on the better-balanced weighting and regression analyses, which agree in showing no association.

Strengths and limitations

Strengths include a large consecutive cohort, complete exposure and 6-hour haemoglobin data, explicit calendar-time adjustment via a flexible spline, three complementary and adequately balanced regression and propensity-score approaches (covariate-adjusted regression, IPTW and overlap weighting) with concordant findings, comprehensive balance diagnostics, and sensitivity analyses for sparse events and unmeasured confounding.

Limitations are substantial. The study is single-centre and retrospective, with residual-confounding risk from variables not captured in the routine record (intrapartum decisions, fluid balance, uterotonic timing

relative to placental delivery). Maternal age was unavailable in the analysis dataset and could not be included in descriptive or adjusted analyses; because maternal age is associated with both obstetric practice and haematological outcomes, this is an important residual-confounding limitation. The IPTW effective sample size for the DCC group was reduced by approximately 41%, indicating reliance on the smaller number of early-period DCC observations; concordance between the IPTW and overlap-weighted analyses mitigates but does not eliminate this concern, and the propensity-score-matched estimate, although concordant with the weighting analyses, is unreliable because matching did not fully balance calendar time (see Main findings). Cord-clamping timing was recorded categorically (0, 30, 60, 120 s), limiting smooth dose–response detection. PPH was clinically recorded rather than measured from quantitative blood loss, and documentation practices may have evolved over the period, producing outcome-ascertainment confounding that calendar-time adjustment only partly addresses. Uterotonic agent was imbalanced but excluded from the propensity model to avoid adjusting for a downstream variable. Transfusion was rare (n = 28), yielding wide confidence intervals despite Firth penalisation. Because clamping time was determined clinically rather than at random, reverse causation is possible: incipient bleeding, uterine atony or the need for urgent neonatal resuscitation may itself prompt earlier clamping, which would bias associations for bleeding-related outcomes. The de-identified dataset did not contain a maternal identifier, so repeat deliveries by the same woman could not be linked and any within-woman correlation is unaccounted for. Balance of a single numeric delivery-date summary does not, on its own, demonstrate covariate balance across the full calendar-time spline or throughout the study period, so residual calendar-time confounding cannot be excluded. The delivery-mode interaction, although clinically motivated and statistically supported, remains exploratory. Generalisability beyond a tertiary university setting in this region is uncertain.

Interpretation in light of other evidence

Our overall null finding for anaemia, PPH and transfusion is consistent with the foundational randomised trial by Andersson and colleagues [6], a term-caesarean trial [7], multiple-pregnancy evidence [17], neonatal-focused preterm evidence [9, 10] and a 2025 caesarean-delivery meta-analysis [8]. The 2025 WHO consolidated postpartum-haemorrhage guidelines retain antenatal anaemia as a modifiable risk factor and endorse implementation packages such as the E-MOTIVE bundle [2, 18], underscoring the value of high-quality maternal-safety data for third-stage practices in real-world cohorts.

An exploratory interaction analysis suggested that the association differed by delivery mode (interaction p = 0.007), with a modestly higher adjusted anaemia risk after delayed clamping among vaginal deliveries but no evidence of increased risk among caesarean deliveries. This finding should be interpreted cautiously because of its subgroup nature and the possibility of residual confounding, and it was not pre-specified in a dated analysis plan. Plausible mechanisms include differences in third-stage physiology, uterotonic timing, blood-loss ascertainment and unmeasured case mix; calendar-time confounding could also differ by delivery mode. Because delivery mode was not randomised and was embedded in evolving clinical practice, this signal should guide prospective evaluation rather than immediate protocol change [17].

Implications for practice and research

These data provide reassuring evidence of no overall association between guideline-concordant DCC and adverse maternal haematological outcomes, consistent with current ACOG [3, 5] and 2025 WHO [2] guidance. Future work should use prospective designs with measured blood loss, pre-specified third-stage protocols (including uterotonic timing relative to placental delivery), continuous cord-clamping timing rather than categorical bins, and pre-stated subgroup hypotheses by mode of delivery.

Conclusions

After calendar-time-adjusted multimethod analysis, DCC ≥ 60 seconds was not associated with worse maternal haematological outcomes overall. The observed delivery-mode divergence for postpartum anaemia is hypothesis-generating and should be evaluated prospectively, particularly in studies with standardised third-stage management, measured blood loss and clearly recorded uterotonic timing.

List of abbreviations

ACOG, American College of Obstetricians and Gynecologists; ATE, average treatment effect; ATO, average treatment effect in the overlap population; BMI, body mass index; CI, confidence interval; DCC, delayed cord clamping; ECC, early cord clamping; Hb, haemoglobin; IPTW, inverse probability of treatment weighting; PPH, postpartum haemorrhage; PS, propensity score; RR, risk ratio; SD, standard deviation; SMD, standardised mean difference; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; WHO, World Health Organization.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Ankara University School of Medicine (decision number 1741076; approval date 26 February 2025). The requirement for informed consent was waived by the same committee because the analysis used retrospective de-identified routine clinical data. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

A privacy-preserving reproducibility package — comprising the de-identified analysis dataset, the full R statistical analysis script, archived analysis outputs, a variable-level data dictionary and the STROBE checklist — is openly available in the cord-clamping-maternal-outcomes repository (https://github.com/Drgoksugoc/cord-clamping-maternal-outcomes) and permanently archived at Zenodo (DOI: 10.5281/zenodo.20315727; https://doi.org/10.5281/zenodo.20315727).

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Authors' contributions

G.A.Y. conceived and designed the study, contributed to data curation and investigation, administered the project, and drafted the manuscript. G.G. designed the statistical methodology, developed the R analysis pipeline, performed the statistical analysis and visualisation, and drafted the manuscript. H.S., B.T., B.Y.B. and E.Ö. contributed to investigation and data curation and critically revised the manuscript. C.S.A. contributed to conceptualisation and methodology and supervised the study. All authors read and approved the final manuscript.

Acknowledgements

We thank the obstetric, anaesthetic and laboratory staff of Ankara University School of Medicine for their contribution to routine clinical data collection.

References

1. Bienstock JL, Eke AC, Hueppchen NA. Postpartum hemorrhage. N Engl J Med. 2021;384(17):1635–45.
2. World Health Organization. Consolidated guidelines for the prevention, diagnosis and treatment of postpartum haemorrhage. Geneva: World Health Organization; 2025.
3. American College of Obstetricians and Gynecologists. Delayed umbilical cord clamping after birth. ACOG Comm Opin 814 Obstet Gynecol. 2020;136(6):e100–6.

4. McDonald SJ, Middleton P, Dowswell T, Morris PS. Effect of timing of umbilical cord clamping of term infants on maternal and neonatal outcomes. Cochrane Database Syst Rev. 2013;(7):CD004074.
5. American College of Obstetricians and Gynecologists. ACOG clinical practice update: an update to clinical guidance for delayed umbilical cord clamping after birth in preterm neonates. Obstet Gynecol. 2025;146(3):442–4.
6. Andersson O, Hellström-Westas L, Andersson D, Clausen J, Domellöf M. Effects of delayed compared with early umbilical cord clamping on maternal postpartum haemorrhage and cord blood gas sampling: a randomised trial. Acta Obstet Gynecol Scand. 2013;92(5):567–74.
7. Purisch SE, Ananth CV, Arditi B, Mauney L, Ajemian B, Heiderich A, et al. Effect of delayed vs immediate umbilical cord clamping on maternal blood loss in term cesarean delivery: a randomized clinical trial. JAMA. 2019;322(19):1869–76.
8. Arora A, Pollack B, Babajanian M, Friedman-Ciment R, Glass M, Kasoff M, et al. Maternal and neonatal outcomes after delayed vs early cord clamping at cesarean delivery: a systematic review and meta-analysis. Am J Obstet Gynecol MFM. 2025;7(6):101680.
9. Seidler AL, Aberoumand M, Hunter KE, Barba A, Libesman S, Williams JG, et al. Deferred cord clamping, cord milking and immediate cord clamping at preterm birth: a systematic review and individual participant data meta-analysis. Lancet. 2023;402(10418):2209–22.
10. Seidler AL, Libesman S, Hunter KE, Barba A, Aberoumand M, Williams JG, et al. Short, medium, and long deferral of umbilical cord clamping compared with umbilical cord milking and immediate clamping at preterm birth: a systematic review and network meta-analysis with individual participant data. Lancet. 2023;402(10418):2223–34.
11. Lummevaara L, Ordén MR, Mykkänen A, Keski-Nisula L. Delayed umbilical cord clamping in elective and nonelective term caesarean delivery. J Gynecol Obstet Hum Reprod. 2024;53(2):102717.
12. Sedgwick PM. Updated guidelines for the reporting of methods and statistical analyses. Acta Obstet Gynecol Scand. 2024;103(1):4–6.
13. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–7.
14. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004;159(7):702–6.
15. Heinze G, Schemper M. A solution to the problem of separation in logistic regression. Stat Med. 2002;21(16):2409–19.
16. VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the E-value. Ann Intern Med. 2017;167(4):268–74.
17. Ruangkit C, Leon M, Hassen K, Baker K, Poeltler D, Katheria A. Maternal bleeding complications following early versus delayed umbilical cord clamping in multiple pregnancies. BMC Pregnancy Childbirth. 2018;18(1):131.

18. Gallos I, Devall A, Martin J, Middleton L, Beeson L, Galadanci H, et al. Randomized trial of early detection and treatment of postpartum hemorrhage. N Engl J Med. 2023;389(1):11–21.
19. Aynağlu Yıldız G, Goc G, Süt H, Turgay B, Yıldırım Baydemir B, Öztürk E et al. Delayed umbilical cord clamping and postpartum maternal outcomes: de-identified analysis dataset and reproducibility package [dataset]. Zenodo; 2026. DOI: 10.5281/zenodo.20315727.

Figures

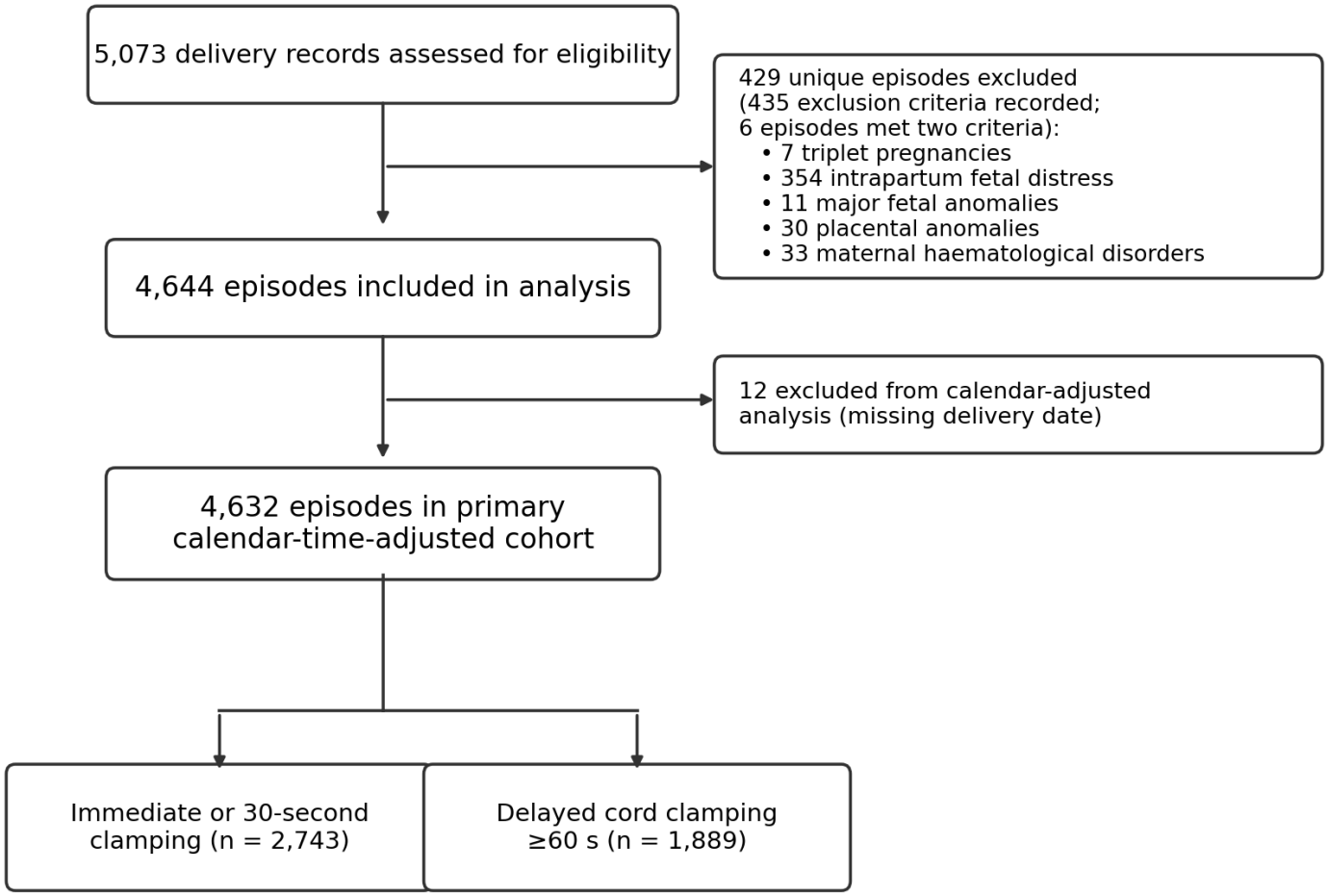


Figure 1

Study flow diagram. From an initial register of 5,073 delivery records, 429 unique episodes were excluded (435 exclusion criteria were recorded because 6 episodes met two criteria: 7 triplet

pregnancies, 354 intrapartum fetal distress, 11 major fetal anomalies, 30 placental anomalies, 33 maternal haematological disorders), leaving 4,644 episodes for analysis. Twelve episodes with missing or invalid delivery dates were excluded from the calendar-adjusted analysis, leaving 4,632 episodes in the primary adjusted cohort (1,889 delayed cord clamping ≥60 s; 2,743 immediate or 30-second clamping).

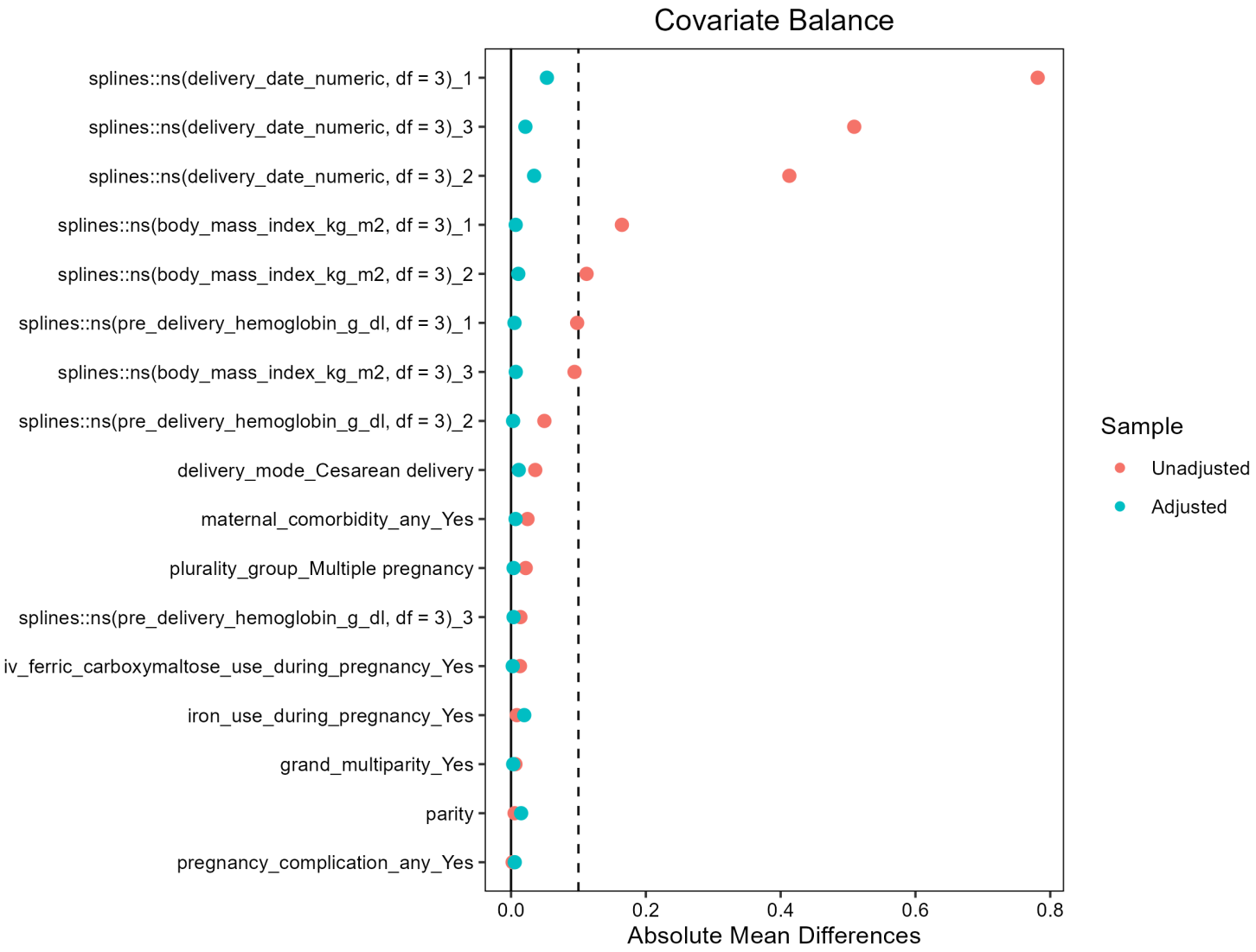


Figure 2

Covariate balance before and after stabilised inverse-probability-of-treatment weighting. Standardised mean differences (SMDs) for each covariate are shown before and after weighting (weights computed after truncation at the 1st and 99th percentiles). The dashed line indicates SMD = 0.10.

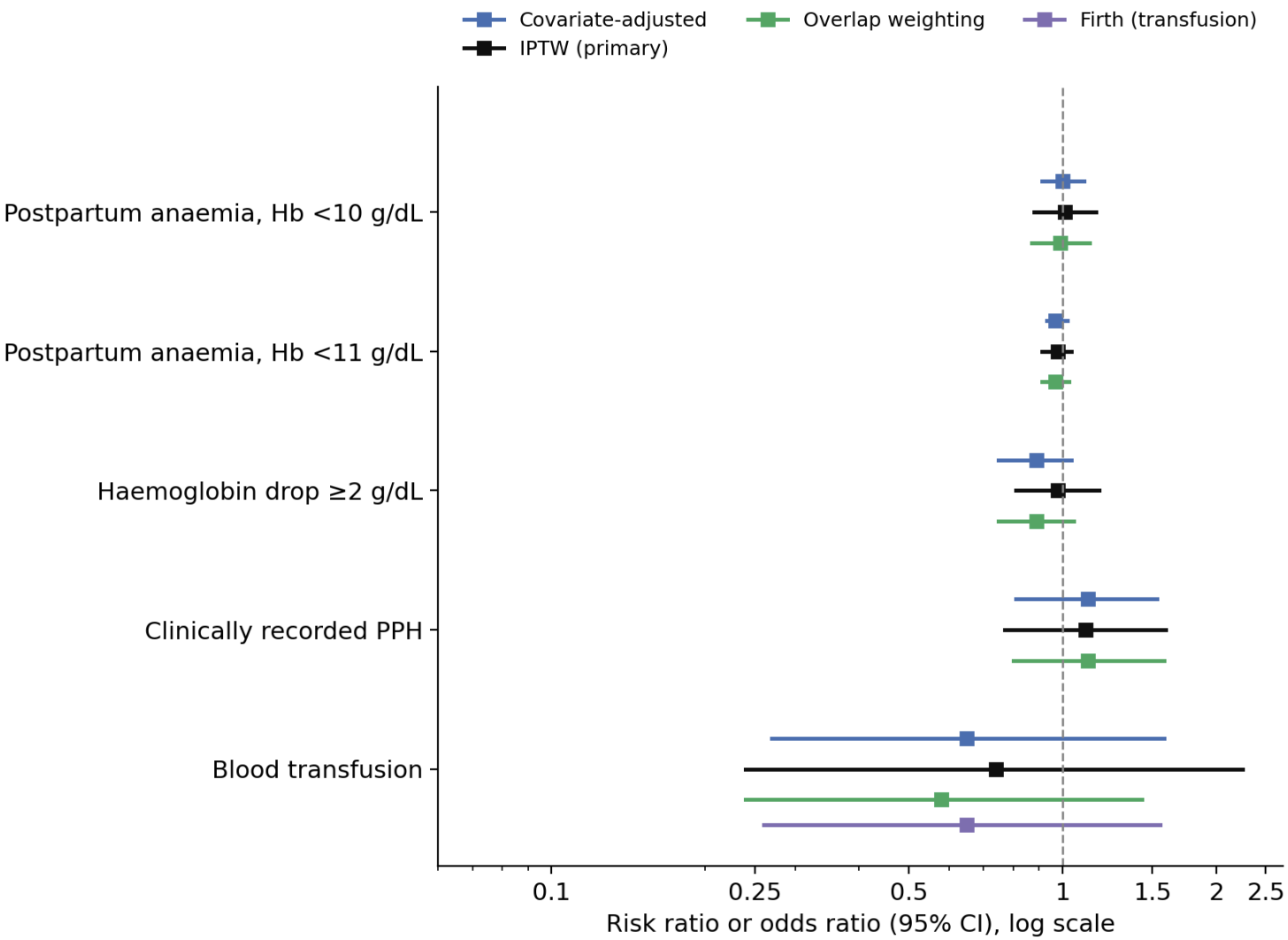


Figure 3

Cross-method estimates for delayed cord clamping ≥60 seconds versus immediate or 30-second clamping across all binary maternal outcomes. Risk ratios are shown under covariate-adjusted modified Poisson regression, stabilised inverse-probability-of-treatment weighting (primary) and overlap weighting — the three approaches that achieved covariate balance. The Firth-penalised logistic odds ratio is additionally reported for the sparse transfusion outcome. The inadequately balanced propensity-score-matched sensitivity analysis is reported separately (Additional file 1, Table S4). Whiskers are 95% confidence intervals.

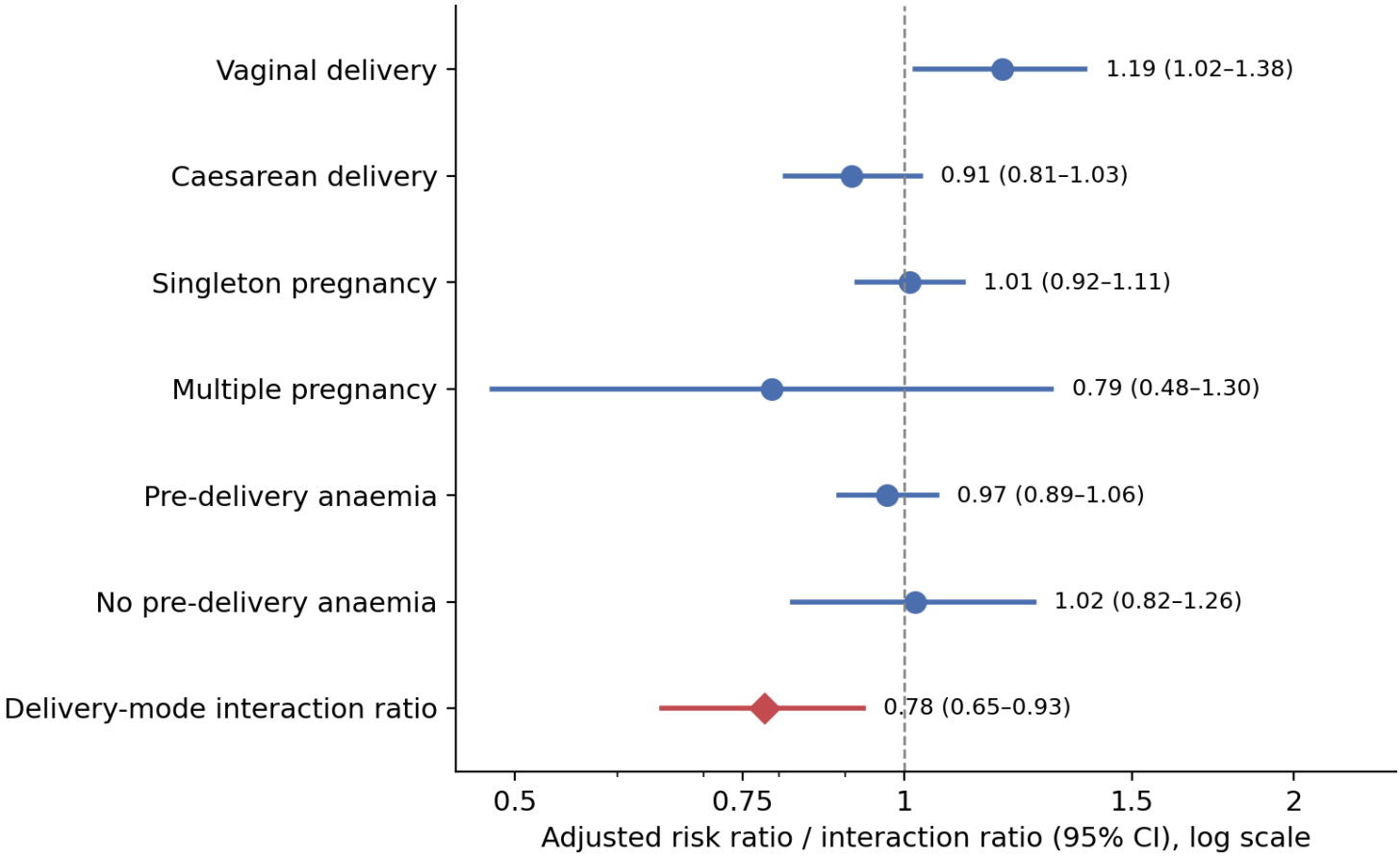


Figure 4

Subgroup forest plot for the primary outcome, postpartum anaemia (Hb <10 g/dL). Adjusted risk ratios with 95% confidence intervals are shown for vaginal delivery, caesarean delivery, singleton pregnancy, multiple pregnancy, pre-delivery anaemia and no pre-delivery anaemia, and the formal delivery-mode interaction-ratio estimate.

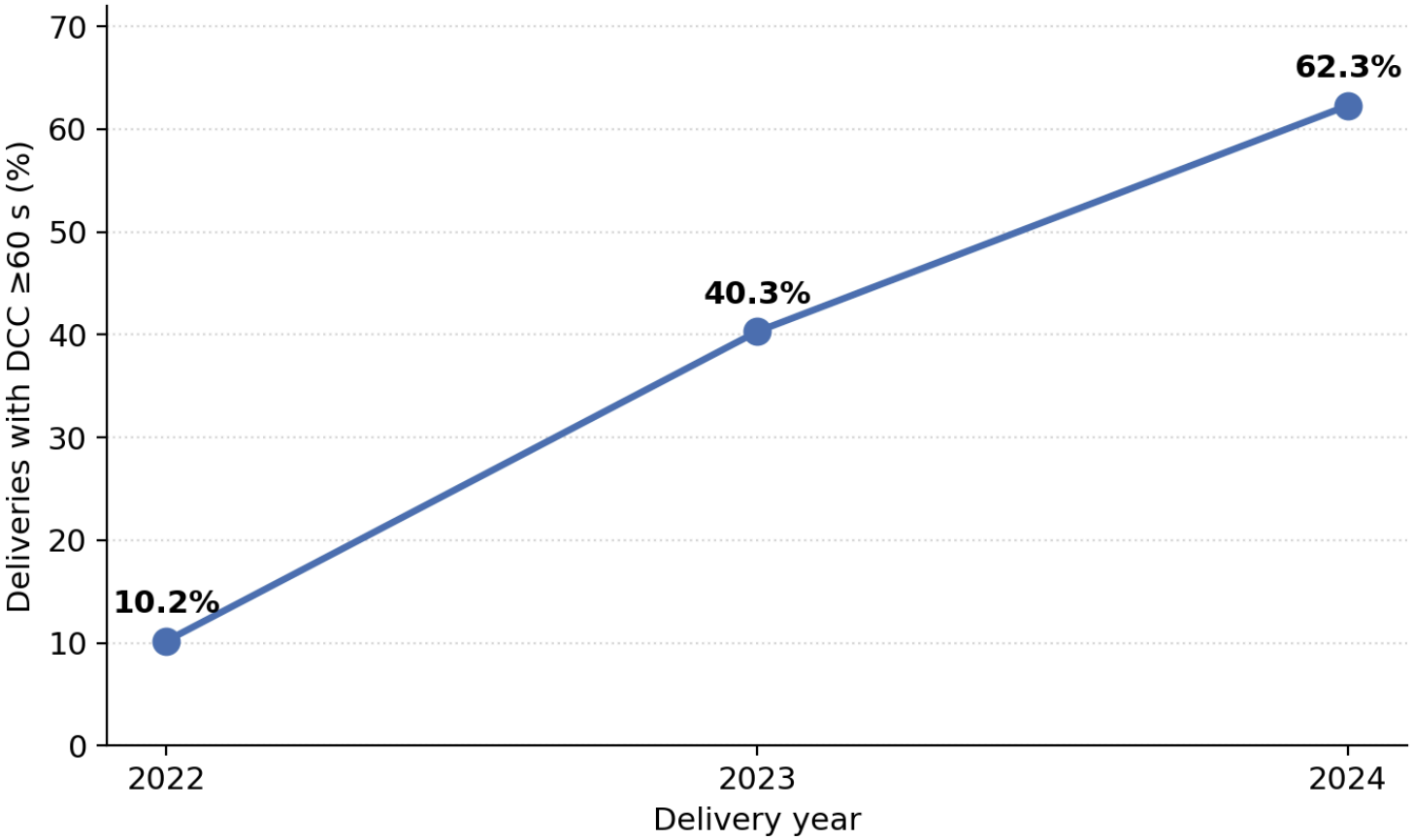


Figure 5

Calendar trend in delayed cord clamping adoption over the study period. The proportion of deliveries with DCC ≥60 s increased from 10.2% in 2022 to 62.3% in 2024.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1SupplementaryMaterial.docx
- Additionalfile2STROBEChecklist.docx