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Original Research Article

Comparison of coagulation changes and venous thromboembolic outcomes between enoxaparin users and non-users undergoing caesarean delivery: A prospective cohort study

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Abstract

Purpose: *To assess the associations of coagulation changes, postpartum venous thromboembolism (VTE) after caesarean delivery, and clinician-selected antenatal prophylaxis with enoxaparin.*
Methods: *This was a prospective observational cohort study at Al-Haboubi Teaching Hospital, Iraq, in which 81 of 181 women received enoxaparin 4,000 anti-Xa IU once daily, and 100 received no pharmacological thromboprophylaxis. International normalised ratio (INR), D-dimer, activated partial thromboplastin time (aPTT) and prothrombin time (PT) were assessed at 12 to 24 hours pre-delivery and on postoperative day 10. VTE observation continued for 42 days. Risk factors for deep vein thrombosis (DVT) were analysed by Firth penalised-likelihood regression.*
Results: *Composite VTE occurred in 6.2 % of enoxaparin users and 17.0 % of non-users (risk ratio 0.36, 95 % confidence interval 0.14–0.94; P = 0.047). After adjustment, use of enoxaparin was associated with reduced odds of DVT (adjusted odds ratio 0.116, 95 % confidence interval 0.02–0.45; P = 0.001). The rise in PT was higher (P = 0.016) but the rise in D-dimer was lower in users (P = 0.011); changes in aPTT and INR were similar. Higher body mass index (BMI) and gestational diabetes mellitus were associated with increased risks of DVT.*
Conclusion: *Prophylactic enoxaparin was associated with a lower occurrence of unadjusted composite VTE and a lower adjusted probability of DVT. Larger, multicentre studies are needed to confirm these observational data, which do not establish causation.*

Keywords: *venous thromboembolism, D-dimer, deep venous thrombosis, enoxaparin, thromboprophylaxis, caesarean section*

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INTRODUCTION

Pregnancy and the postpartum period are associated with major physiological changes in haemostasis, including increased procoagulant activity, decreased endogenous anticoagulant activity and impaired fibrinolysis. These alterations result in an increased risk of venous thromboembolism (VTE) [1,2]. Caesarean delivery increases the risk of thrombosis due to surgical tissue damage, vascular stress, and decreased mobility. Advanced maternal age, obesity, history of VTE, thrombophilia, hypertensive diseases, diabetes, and prolonged

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immobilisation are other factors that might increase an individual's risk [1–4]. Pulmonary embolism (PE) is still a potentially fatal outcome of pregnancy-related VTE, especially in the first six weeks after delivery, but deep vein thrombosis (DVT) is a major contributor to maternal morbidity [1–3,5]. Therefore, obstetric care should include adequate thromboprophylaxis and a structured risk assessment.

Low-molecular-weight heparins (LMWH) have predictable anticoagulant effects, are easy to administer subcutaneously, and are generally safe; therefore, they are commonly used for obstetric thromboprophylaxis, particularly enoxaparin [3,4]. Current guidelines support pharmacological prophylaxis and full VTE risk assessment in women with sufficiently high thrombotic risk. However, the therapy thresholds, dose selection, timing and duration vary in different guidelines and healthcare systems [3,4]. Perioperative considerations, neuraxial anaesthesia, and thromboembolic protection versus bleeding risk must be considered in clinical decision-making. Prophylactic enoxaparin is not usually randomly allocated, but rather according to the clinical assessment of the treating obstetrician. Consequently, women treated with enoxaparin may systematically differ in baseline thrombotic-risk profile from untreated women, which requires analytical adjustment and careful interpretation of between-group comparisons.

The relationship between longitudinal haemostatic changes, postpartum thromboembolic events, and prophylactic enoxaparin administration by clinicians before caesarean birth remains to be determined. Prothrombin time (PT) and activated partial thromboplastin time (aPTT) are global coagulation assays and do not directly reflect the anticoagulant effect of enoxaparin [6]. International normalised ratio (INR) is a standardised result of PT. Serial changes in these measurements should not be interpreted as direct measures of low-molecular-weight heparin activity in this setting, but they may aid in characterising more general peripartum haemostatic patterns. The physiological elevation of D-dimer during pregnancy and the puerperium decreases its diagnostic specificity and precludes its use as a standalone diagnostic test for VTE, although it may provide additional information [1,2,5]. Previous studies have evaluated postoperative D-dimer trajectories and routine enoxaparin dosing after caesarean delivery [7,8]. However, the generalisability to clinician-selected prophylaxis in routine care is hampered by variation in drug allocation, laboratory testing, imaging pathways and follow-up. A study from Al-Nasiriyah has previously compared maternal outcomes following caesarean and vaginal deliveries [9], but serial coagulation changes and objectively verified thromboembolic outcomes were not assessed. Evidence from Iraqi obstetric settings has not been as widely reported, and prospective routine-care studies linking serial coagulation measures to empirically validated postpartum VTE outcomes are few.

Thus, the present study aimed to investigate the association between clinician-selected prophylactic enoxaparin use before caesarean delivery, longitudinal changes in PT, aPTT, INR, and D-dimer, and objectively confirmed VTE outcomes among women undergoing caesarean delivery in Al-Nasiriyah, Iraq.

METHODS

Study design and setting

This single-centre prospective observational cohort study was conducted at Al-Haboubi Teaching Hospital in Al-Nasiriyah, Dhi Qar, Iraq, from December 2025 to June 2026. Eligible women were recruited prior to caesarean birth and classified as unexposed to pharmacological thromboprophylaxis or exposed to prophylactic enoxaparin according to routine clinical care. The attending obstetrician made the decision to administer enoxaparin; investigators did not assign or influence this decision; no randomisation was performed. The day-10 reassessment was performed at the scheduled obstetric follow-up visit and preoperative evaluations were performed in the hospital. Clinical surveillance for venous thromboembolism was continued for 42 days postpartum, with any suspected events being referred for expert diagnostic assessment.

Participants and eligibility criteria

Women aged 18–45 years undergoing elective or emergency caesarean delivery were consecutively recruited after providing written informed consent. Exclusion criteria were coagulation disorders, previous heparin-induced thrombocytopenia, active bleeding, therapeutic-dose anticoagulation, concomitant use of additional anticoagulant or antiplatelet agents, pre-existing thrombocytopenia, severe anaemia requiring preoperative transfusion, hepatic or renal disease associated with coagulation abnormalities, and haematological malignancy or autoimmune disease affecting haemostasis. The final analytic cohort comprised 181 women who

completed both laboratory assessments and the 42-day follow-up.

Sample size and recruitment

The study proposal specified an intended sample of approximately 160–180 participants. Recruitment continued until 181 women completed the required study assessments and 42-day follow-up. The final analytic cohort comprised 181 women, including 81 who received antenatal prophylactic enoxaparin and 100 who did not receive antenatal pharmacological thromboprophylaxis. Some initially recruited women did not complete follow-up and were not included in the final analytic cohort. A complete recruitment and attrition log for these women was not available; therefore, their number could not be reported.

Data collection and definition of exposure

Maternal age, body mass index (BMI), parity, previous miscarriages, gestational hypertension, gestational diabetes mellitus and type of caesarean delivery were obtained from clinical records and structured interviews. Exposure to enoxaparin in pregnancy was defined as 4,000 anti-Xa IU subcutaneously once daily. The attending obstetrician decided when and for how long to start treatment. Enoxaparin was generally discontinued 24–72 hours before caesarean delivery; however, the exact interval between the last dose and preoperative blood sampling was not available for all exposed participants. The unexposed group was women with no recorded or reported antenatal use of enoxaparin or other pharmacological thromboprophylaxis.

Blood collection and lab measurements

Venous blood was sampled 12–24 hours before caesarean section and on the 10th postoperative day. Coagulation samples were collected in 3.2 % sodium citrate tubes, processed within 4 h to obtain platelet-poor plasma, and tested [10,11]. Prothrombin time (PT) and activated partial thromboplastin time (aPTT) were assessed on a GENEX semi-automatic coagulation analyser (Genex Laboratories LLC, USA) with BIO-TP reagent (BIO-LABO SA, France) and HEMOSTAT aPTT-EL reagent (HUMAN GmbH, Germany). The international normalised ratio (INR) was automatically derived from PT using the reagent-specific International Sensitivity Index [12]. D-dimer was measured in fibrinogen-equivalent units (FEU) by the ZyBio D-Dimer Assay (REF 0602803) on an EXI 1800 chemiluminescence immunoassay analyser (ZyBio Inc., China). Standard internal quality control procedures were performed before sample analysis. The manufacturer's analytical measurement range was 10–20,000 ng/mL FEU; levels above the local reporting ceiling were reported as > 10,000 ng/mL FEU.

Clinical monitoring and evaluation of results

Participants were monitored for VTE during the 42-day postpartum period after their evaluation on postoperative day 10. Women with symptoms were referred for assessment by a specialist. Suspected deep vein thrombosis (DVT) was evaluated using lower-extremity compression Doppler ultrasonography and suspected pulmonary embolism (PE) was evaluated with clinically indicated imaging. D-dimer was not used as a single diagnostic test but was interpreted in conjunction with clinical and imaging findings [2,5]. The outcomes were objectively confirmed DVT, PE, and a composite of any VTE, with women who experienced both events counted once.

Statistical analysis

Data management and traditional analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Continuous data were expressed as mean ± standard deviation and median (interquartile range), and categorical variables as number (percentage). Normality was assessed with the Shapiro–Wilk test. Group comparisons were performed using the independent-samples t-test with Welch's adjustment or the Mann–Whitney U test as appropriate. Change scores (postoperative day 10 minus preoperative values) were compared with the Mann–Whitney U test. Categorical variables were analysed using the chi-square test with Yates' correction for continuity or Fisher's exact test. Hedges' g was described in descriptive terms.

Risk ratios (RRs), odds ratios (ORs) and absolute risk differences are presented with 95 % confidence intervals (CIs); risk ratios were calculated using the Katz method, odds ratios using the Woolf method and absolute risk differences using the Newcombe method. DVT-related variables were evaluated by exploratory logistic regression. The full model contained enoxaparin exposure, previous miscarriage, gestational diabetes mellitus, gestational hypertension, age, and body mass index. Given the small number of DVT events, Firth penalised likelihood regression with profile likelihood confidence intervals was used as the main adjusted analysis, with standard maximum likelihood estimates reported for comparison

[13,14]. A sensitivity analysis was conducted with a parsimonious model including enoxaparin exposure, previous miscarriage and gestational diabetes mellitus. The presence of multicollinearity was assessed based on variance inflation factors. PE was not modelled because only five events occurred.

In the main rank-based evaluation, D-dimer values > 10,000 ng/mL FEU were assigned a value of 10,000 ng/mL FEU. Sensitivity analyses assigned values of 15,000 and 50,000 ng/mL FEU and repeated the comparison after excluding these observations. All tests were two-sided and $P < 0.05$ was regarded as statistically significant.

Ethics considerations

Ethical approval for the study was obtained from the Research Ethics Committee of the College of Pharmacy, University of Thi-Qar, Iraq (approval no. TH PH REC 2025 06-07; dated 7 June 2025), and the study was conducted in accordance with the Declaration of Helsinki [15]. Written informed consent was obtained from all participants before enrolment. Participation was voluntary, and all data were handled and stored with due regard for privacy and confidentiality.

RESULTS

Participant characteristics

The final analytic cohort comprised 181 women: 81 received antenatal prophylactic enoxaparin and 100 received no antenatal pharmacological thromboprophylaxis. All participants completed the scheduled laboratory assessments and 42-day follow-up. The participant flow is presented in Figure 1.

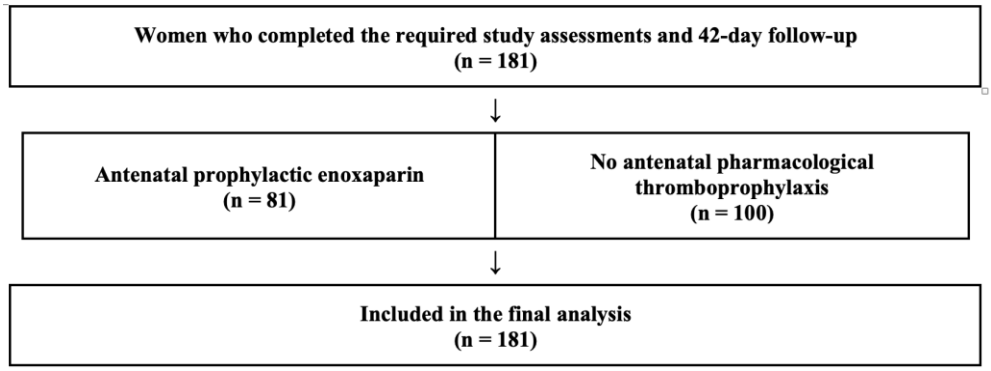

Figure 1: Participant flow diagram. ***Note:*** Some initially recruited women did not complete the required follow-up and were not included in the final analytic cohort. A complete recruitment and attrition log for these women was not available; therefore, the number of non-completers is not reported

Table 1: Obstetric and demographic characteristics by thromboprophylaxis group

Variable	Enoxaparin Mean ± SD / n (%)	Enoxaparin Median (IQR)	No enoxaparin Mean ± SD / n (%)	No enoxaparin Median (IQR)	P value
Panel A. Continuous characteristics					
Age (years)	28.57 ± 6.24	27.00 (24.00–34.00)	27.86 ± 5.93	27.00 (23.00–32.00)	0.462
BMI (kg/m²)	26.18 ± 3.48	25.50 (23.00–29.00)	24.84 ± 2.78	25.00 (23.00–27.00)	0.013
Parity	1.72 ± 1.60	1.00 (0.00–3.00)	1.88 ± 1.47	2.00 (1.00–3.00)	0.320
Previous miscarriages, number	0.98 ± 1.14	1.00 (0.00–1.00)	0.33 ± 0.88	0.00 (0.00–0.00)	<0.001
Panel B. Categorical characteristics					
Previous miscarriage (≥1)	46 (56.8%)		19 (19.0%)		<0.001
Gestational hypertension	25 (30.9%)		12 (12.0%)		0.003
Gestational diabetes mellitus	19 (23.5%)		10 (10.0%)		0.024
Elective caesarean delivery	80 (98.8%)		92 (92.0%)		0.044

BMI denotes body mass index. The age and parity of the groups were comparable. Additionally, the enoxaparin users' BMI (P = 0.013), number of previous miscarriages (P < 0.001), the frequency of at least one previous miscarriage, gestational hypertension, gestational diabetes mellitus, and elective caesarean birth were significantly higher (all P ≤ 0.044; Table 1). Given these baseline imbalances, comparisons between the enoxaparin and no-enoxaparin groups are subject to confounding by indication and should be interpreted as associations rather than estimates of the causal effect of enoxaparin.

Coagulation parameters

Coagulation parameters were assessed 12–24 hours before caesarean section and on the tenth day postpartum (Tables 2 and 3). Data are presented as mean ± standard deviation and median (interquartile range). Welch's t-test was used to analyse preoperative PT and aPTT and aPTT on day 10, and the other comparisons were made using the Mann–Whitney U test. g is the standardised mean difference (enoxaparin minus no enoxaparin) by Hedges. Nine postoperative D-dimer values above the local reporting limit were treated as right-censored at 10,000 ng/mL FEU. PT and INR were lower in the enoxaparin group before the operation (both P < 0.001), while aPTT and D-dimer measurements were similar. Enoxaparin users had lower aPTT values on postoperative day 10 (P = 0.035). PT, INR and D-dimer levels did not differ significantly (Table 2). Changes were calculated by subtracting the preoperative value from the value recorded on postoperative day 10. The Mann–Whitney U test was employed for comparisons; Hedges' g is described qualitatively. The increase in prothrombin time was greater in the enoxaparin group (P = 0.016), although the increase in D-dimer was smaller (P = 0.011).

Thromboembolic outcomes

The thromboembolic outcomes of objectively verified DVT, PE, and composite VTE events over the 42-day postpartum monitoring are presented in Table 4.

Exploratory multivariable analysis of factors associated with deep vein thrombosis

The complete and parsimonious multivariable models are shown in Table 5. The main adjusted results were the Firth penalised-likelihood estimates, with the parsimonious model used for sensitivity analysis.

Table 2: Coagulation indices before caesarean section and on the tenth day after surgery

Variable	Enoxaparin Mean ± SD	Enoxaparin Median (IQR)	No enoxaparin Mean ± SD	No enoxaparin Median (IQR)	P value	Hedges' g
Panel A. Preoperative assessment (12–24 h before caesarean delivery)						
PT (s)	11.94 ± 1.69	12.10 (11.00–12.80)	12.67 ± 0.96	12.70 (12.00–13.20)	<0.001	−0.540
aPTT (s)	28.67 ± 4.62	28.40 (24.50–32.00)	29.64 ± 5.13	29.35 (25.45–33.40)	0.186	−0.195
INR	0.98 ± 0.14	1.00 (0.90–1.00)	1.03 ± 0.09	1.00 (1.00–1.00)	<0.001	−0.439
D-dimer (ng/mL FEU)	1914.69 ± 1780.49	1293.90 (800.00–2300.00)	1928.02 ± 1978.83	1174.50 (759.77–2123.50)	0.401	−0.007
Panel B. Postoperative day 10						
PT (s)	13.83 ± 1.77	13.80 (12.90–15.00)	14.00 ± 1.32	14.00 (13.00–15.00)	0.479	−0.110
aPTT (s)	29.49 ± 3.77	29.00 (27.00–32.00)	30.76 ± 4.31	31.00 (27.80–34.00)	0.035	−0.311
INR	1.19 ± 0.19	1.15 (1.10–1.30)	1.23 ± 0.19	1.20 (1.10–1.30)	0.177	−0.190
D-dimer (ng/mL FEU)	2396.15 ± 2476.03	1330.00 (980.00–3100.00)	3159.16 ± 3106.07	1765.00 (980.00–3722.50)	0.238	−0.267

Table 3: Modifications in coagulation metrics from the preoperative evaluation to postoperative day 10

Variable	Enoxaparin Mean ± SD	Enoxaparin Median (IQR)	No enoxaparin Mean ± SD	No enoxaparin Median (IQR)	P value	Hedges' g
ΔPT (s)	1.89 ± 1.53	1.60 (1.00–2.70)	1.33 ± 1.24	1.30 (0.60–2.00)	0.016	0.400
ΔaPTT (s)	0.81 ± 3.81	1.90 (−2.00–3.00)	1.12 ± 4.56	1.60 (−0.25–3.38)	0.648	−0.073
ΔINR	0.22 ± 0.19	0.20 (0.10–0.30)	0.20 ± 0.17	0.20 (0.10–0.30)	0.477	0.074
ΔD-dimer (ng/mL FEU)	481.46 ± 1255.50	304.00 (−135.00–1000.00)	1231.14 ± 1861.84	438.50 (58.19–1651.02)	0.011	−0.461

Table 4: Outcomes of thromboembolism and unadjusted effect estimates categorised by thromboprophylaxis group

Outcome	Enoxaparin n (%)	No enoxaparin n (%)	RR (95% CI)	OR (95% CI)	ARD, percentage points (95% CI)	P-value
Deep vein thrombosis	5/81 (6.2)	15/100 (15.0)	0.41 (0.16–1.08)	0.37 (0.13–1.07)	8.8 (−0.6–17.8)	0.100
Pulmonary embolism	2/81 (2.5)	3/100 (3.0)	0.82 (0.14–4.81)	0.82 (0.13–5.02)	0.5 (−5.9–6.3)	1.000
Any VTE (DVT and/or PE)	5/81 (6.2)	17/100 (17.0)	0.36 (0.14–0.94)	0.32 (0.11–0.91)	10.8 (1.2–20.1)	0.047

Note: RR denotes risk ratio; OR signifies odds ratio; ARD refers to absolute risk difference (comparing no enoxaparin to enoxaparin); CI represents confidence interval; VTE indicates venous thromboembolism. The Katz, Woolf, and Newcombe methodologies were employed for the confidence intervals of RR, OR, and ARD, respectively. Individuals with both DVT and PE were included once in the aggregate result. DVT was observed in 5 out of 81 enoxaparin recipients (6.2 %) and in 15 out of 100 non-recipients (15.0 %; P = 0.100). Pulmonary embolism was observed in 2 out of 81 cases (2.5 %) and 3 out of 100 cases (3.0 %), respectively (P = 1.000). The occurrence of composite VTE was lower in users (6.2 % compared to 17.0 %; RR 0.36, 95 % CI 0.14–0.94; P = 0.047), resulting in an absolute risk difference of 10.8 percentage points (95 % CI 1.2–20.1).

Table 5: Exploratory multivariable analysis of factors associated with deep vein thrombosis

Factor	aOR (standard ML)	95 % CI	P-value	aOR (Firth)	95 % CI (profile likelihood)	*P*-value
Panel A. Full multivariable model						
Enoxaparin (LMWH) use	0.085	0.02–0.43	0.003	0.116	0.02–0.45	0.001
Previous miscarriage (≥1)	3.382	0.78–14.65	0.103	3.039	0.76–12.40	0.114
Gestational diabetes mellitus	8.568	1.94–37.89	0.005	7.035	1.85–30.62	0.004
Gestational hypertension	1.536	0.38–6.23	0.548	1.523	0.39–5.61	0.535
Age (per year)	1.059	0.96–1.17	0.247	1.053	0.96–1.16	0.275
BMI (per kg/m²)	1.265	1.08–1.49	0.004	1.237	1.07–1.45	0.005
Panel B. Parsimonious multivariable model (sensitivity analysis)						
Enoxaparin (LMWH) use	0.131	0.03–0.52	0.004	0.153	0.04–0.52	0.002
Previous miscarriage (≥1)	5.358	1.50–19.19	0.010	5.003	1.48–17.94	0.010
Gestational diabetes mellitus	11.034	2.92–41.67	<0.001	9.607	2.86–37.27	<0.001

Note: aOR, adjusted odds ratio; CI, confidence interval; ML, maximum likelihood; BMI, body mass index. The full model included 181 subjects and 20 DVT events (3.33 events per candidate factor); the parsimonious model had three factors (6.67 events per factor). Firth applies profile-likelihood confidence intervals to help reduce bias from small sample sizes and limited data

The administration of enoxaparin correlated with reduced likelihood of DVT in the comprehensive Firth model (adjusted OR 0.116, 95 % CI 0.02–0.45; P = 0.001). Increased BMI (adjusted OR 1.237 per kg/m², 95 % CI 1.07–1.45; P = 0.005) and gestational diabetes mellitus (adjusted OR 7.035, 95 % CI 1.85–30.62; P = 0.004) were associated with a higher likelihood of DVT. The additional covariates were not statistically significant.

Within the parsimonious Firth model, enoxaparin was also associated with a lower probability of DVT (adjusted OR 0.153, 95 % CI 0.04–0.52; P = 0.002). Previous miscarriage (adjusted OR 5.003, 95 % CI 1.48–17.94; P = 0.010) and gestational diabetes mellitus (adjusted OR 9.607, 95 % CI 2.86–37.27; P < 0.001) were associated with higher odds. The results showed a consistent trend for the different estimating methods, with all variance inflation factors less than 1.5.

Sensitivity analysis of postoperative D-dimer levels (censored)

Nine D-dimer levels after surgery were > 10,000 ng/mL FEU. Assigning values of 10,000, 15,000, or 50,000 ng/mL FEU yielded non-significant comparisons between groups (P = 0.238, 0.235, and 0.235). Leaving out these observations did not change the interpretation (P = 0.320).

DISCUSSION

Clinician-selected prophylactic enoxaparin was associated with lower composite VTE occurrence during the 42-day postpartum follow-up (6.2 % vs 17.0 %; RR 0.36, 95 % CI 0.14–0.94). Crude DVT occurrence was lower but not statistically significant, and PE events were too few for firm

conclusions. Lower DVT odds persisted after exploratory adjustment. Enoxaparin users also had a smaller D-dimer increase, whereas PT, aPTT, and INR showed no coherent LMWH-related pattern. Higher BMI and gestational diabetes mellitus were associated with greater DVT odds; the miscarriage association varied by model. These observational findings do not establish causality.

The lower composite VTE occurrence is clinically plausible and consistent with risk-based LMWH use in pregnancy [4]. However, a meta-analysis of 14 studies involving 11,944 postpartum women found no statistically significant reduction in VTE, with uncommon events and an imprecise pooled estimate [16]. A Cochrane review likewise considered the benefits and harms of perinatal thromboprophylaxis uncertain because the available trials were small [17]. Differences in treatment timing, baseline risk, follow-up, and outcome ascertainment limit direct comparison with this routine-care cohort.

The composite result was driven mainly by fewer DVT events, whereas PE rates were similar. Although the crude DVT comparison was not statistically significant, the association with lower DVT odds persisted in the Firth analysis. Enoxaparin users had a higher BMI and higher frequencies of previous miscarriage, gestational hypertension, and gestational diabetes mellitus, indicating preferential prescribing to women with less favourable risk profiles. Such imbalances may attenuate crude associations, although confounding by indication, residual confounding, and sparse-event bias remain possible. A multicentre routine-care cohort also reported institutional variation and greater prophylaxis use among women with recognised risk factors [18]. In a randomised trial, weight-based dosing more often achieved prophylactic anti-factor Xa concentrations than fixed dosing, but no VTE occurred in either group [8].

D-dimer requires longitudinal interpretation. Day-10 concentrations were comparable, but the increase from baseline was smaller among enoxaparin users. D-dimer rises during pregnancy and may increase further after caesarean delivery [19]; therefore, the observed difference cannot establish protection or serve as a VTE surrogate. Miyamoto et al. reported declining D-dimer between postoperative days 1 and 6 among women receiving postoperative enoxaparin [7], but their retrospective, D-dimer-guided design limits comparison. Unavailable last-dose timing also prevents inference of an immediate pharmacodynamic effect. Sensitivity analyses of values above the reporting ceiling did not alter the day-10 comparison.

PT, aPTT, and INR did not demonstrate a consistent pattern attributable to a direct enoxaparin effect. PT increased more among users, but PT and INR were lower at baseline and comparable by day 10; the lower day-10 aPTT was not supported by a between-group difference in longitudinal change. These findings may reflect baseline differences and peripartum haemostatic variation. PT and aPTT do not reliably quantify prophylactic LMWH, whereas anti-factor Xa is more specific when measurement is clinically indicated [6]. INR primarily standardises monitoring of vitamin K antagonists [12]. Each 1-kg/m² increase in BMI was associated with greater DVT odds in the full Firth model (adjusted OR 1.24, 95 % CI 1.07–1.45), consistent with evidence linking obesity to pregnancy-associated VTE [20]. Infection, transfusion, and coagulopathy have also been associated with VTE after caesarean delivery among women with obesity [21].

The miscarriage association was model-dependent: it was non-significant in the full model but emerged in the parsimonious analysis. Antiphospholipid syndrome provides a plausible link with recurrent pregnancy loss, whereas evidence for inherited thrombophilia is less consistent [22]. This study recorded any previous miscarriage, not recurrent loss, and did not perform thrombophilia testing. The finding is therefore hypothesis-generating and should not be interpreted as an independent causal predictor.

Gestational hypertension was more frequent among enoxaparin users, but its adjusted estimate was imprecise and non-significant (adjusted OR 1.52, 95 % CI 0.39–5.61). Hypertensive disorders, particularly pre-eclampsia, have been linked to postpartum VTE [23], but definitions often combine conditions of differing severity. The present analysis of gestational hypertension alone, together with few events, neither confirms nor excludes a clinically relevant association.

Gestational diabetes mellitus remained associated with higher DVT odds in both Firth models, although the wide confidence intervals indicate uncertainty. A 2024 meta-analysis reported a modest association with pregnancy-associated VTE [20], whereas a 2025 meta-analysis found an antepartum association but no clear postpartum association [24]. The stronger estimate here may reflect restriction to

caesarean delivery and the small number of events; larger cohorts are required.

Strengths include prospective exposure documentation, consecutive recruitment, within-participant assessment of coagulation parameters, complete 42-day follow-up, and objective imaging of suspected events. Firth penalised-likelihood regression was used to reduce small-sample bias and mitigate potential separation [13,14], although it cannot eliminate residual confounding arising from non-random treatment assignment.

Clinically, the findings support structured risk assessment rather than universal prophylaxis. The association between clinician-selected enoxaparin and lower DVT odds is consistent with guidance favouring LMWH when pharmacological prophylaxis is indicated and recommending institution-specific protocols [3]. This study cannot determine optimal timing or duration, and the BMI, gestational diabetes mellitus, and miscarriage findings require external validation before influencing local thresholds. In symptomatic postpartum women, D-dimer should not be interpreted alone; suspected VTE requires objective diagnostic evaluation [25].

Limitations of this study

Important limitations include clinician-directed prescribing, baseline risk imbalances, and possible confounding by indication [26]. Only 20 DVT events informed the adjusted model, creating sparse-data imprecision [27]; PE events were insufficient for modelling. Last-dose timing, adherence, and cumulative exposure were not fully documented. Symptom-triggered evaluation may have missed asymptomatic VTE, the single-centre setting limits generalisability, and measurements at only two time points may have missed early postoperative changes. The findings should therefore be considered exploratory.

CONCLUSION

In this prospective observational cohort, clinician-selected prophylactic enoxaparin before caesarean delivery was associated with lower unadjusted composite VTE occurrence and lower adjusted DVT odds during the 42-day postpartum follow-up. Enoxaparin users also had a smaller increase in D-dimer, whereas changes in PT, aPTT, and INR showed no consistent LMWH-related pattern. Higher BMI and gestational diabetes mellitus were associated with greater DVT odds, while the miscarriage association varied by model. These findings support a structured, risk-based approach but do not establish causality. Larger multicentre studies with standardised exposure assessment are needed.

DECLARATIONS

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Ethical approval

The study was approved by the Research Ethics Committee of the College of Pharmacy, University of Thi-Qar, Iraq (approval no. TH PH REC 2025 06-07; dated 7 June 2025) and was conducted in accordance with the Declaration of Helsinki. All participants gave their written informed consent before joining the study.

Accessibility of data and resources

The study data can be obtained from the corresponding author upon making a reasonable request.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Authors' contributions

Entidhar Jameel Sadoon was responsible for the conceptualisation and design of the study, development of the protocol and methodology, recruitment of participants, collection of clinical data and samples, laboratory analyses, data management, statistical evaluation, interpretation of results, preparation of tables and figures, and drafting and revising the manuscript. Usama Kadem Radi oversaw and conducted a comprehensive assessment of the manuscript. The academic supervision was performed by Wafa S. Abdulredha and the text was critically assessed. All contributors examined and

sanctioned the final document and consented to be responsible for its precision and authenticity.

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