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ORIGINAL ARTICLE

Quantitative and calculated estimated blood loss in cesarean deliveries for twin and singleton pregnancies: a retrospective analysis

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Abstract

Purpose This study retrospectively assessed blood loss during cesarean deliveries for twin and singleton pregnancies using two distinct methods, quantitative estimation measured during cesarean sections and hematocrit-based calculated estimation.

Methods We included scheduled cesarean deliveries for twin or singleton pregnancies at ≥ 34 weeks of gestation. Quantitative blood loss was recorded based on the blood volume in the graduated collector bottle and by weighing the blood-soaked textiles during cesarean sections. The blood loss was calculated using the change in hematocrit levels before and after the cesarean delivery.

Results We evaluated 403 cases including 44 twins and 359 singletons. Quantitative blood loss during cesarean section was significantly higher in twin pregnancies than that in singleton pregnancies (1117 [440] vs 698 [378] mL; $p < 0.001$). However, no significant differences were observed in the calculated blood loss between the two groups on the day after delivery (487 mL [692 mL] vs 507 mL [522 mL]; $p = 0.861$). On post-delivery days 4–5, twin pregnancies were associated with a significantly higher calculated blood loss than singleton pregnancies (725 [868] mL vs 444 [565] mL, $p = 0.041$). Although a significant moderate correlation between quantitative and calculated blood loss was observed in singleton pregnancies ($r = 0.473$, $p < 0.001$), no significant correlation was observed between twin pregnancies ($r = 0.053$, $p = 0.735$).

Conclusion Quantitative blood loss measurements during cesarean section may be clinically insufficient in twin pregnancies. Incorporating blood tests and continuous assessments are warranted for enhanced blood loss evaluation, especially in twin pregnancies, owing to the risk of persistent bleeding.

Keywords Calculated blood loss · Cesarean sections · Postpartum hemorrhage · Quantitative blood loss · Twin pregnancy

Introduction

The global incidence of twin births has increased, influenced by the trend toward delayed childbearing and advancements in medically assisted reproduction technologies [1]. From 2010 to 2015, 12.0 twin deliveries per 1000 deliveries were reported worldwide, resulting in over 1.6 million sets of twins born annually [2]. Twin pregnancies have been associated with an increased risk of postpartum hemorrhage with studies indicating a risk of 2–8 times higher than that of singleton pregnancies [3–5]. The cesarean delivery rate for twin pregnancies is notably high with approximately 75% of twins in the United States delivered via cesarean section between 2006 and 2013 [6] and 82.7% in Japan in 2014 [7]. Furthermore, cesarean sections are known to further increase the risk of hemorrhage than vaginal deliveries [8, 9]. While 54–93% of maternal fatalities from obstetric hemorrhage can be potentially averted, a delayed response to hemorrhage is primarily caused by inaccurate blood loss assessments [10]. As postpartum hemorrhage is the leading cause of maternal mortality [11–13], a better understanding of the characteristics of blood loss assessment in cesarean deliveries for twin pregnancies is crucial.

Although no consensus exists on the method for assessing postpartum blood loss, three primary approaches have been commonly used, visual, quantitative, and calculated blood loss estimation [14, 15]. Visual estimation that has

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been used conventionally is subjective and frequently inaccurate [16, 17]. Quantitative methods, which involve a volumetric technique with a graduated collector bag or a gravimetric approach by weighing blood-soaked textiles, provide objectivity. However, their accuracy can be compromised by potential mixing with amniotic fluid and uncollected blood loss [18–20]. To address these limitations, clinicians have employed calculated estimations leveraging laboratory parameters such as pre- and post-delivery hematocrit or hemoglobin, especially in interventional studies [16, 21, 22]. Despite the potential for the method choice to affect the evaluation of blood loss, the studies examining the differences in blood loss patterns between twin and singleton pregnancies in cesarean deliveries using quantitative and calculated methods are limited. Furthermore, although a few studies have reported a moderate correlation between quantified and calculated estimates in singleton deliveries [15, 23], the correlation in twin deliveries remains insufficiently explored.

Therefore, in this study, we aimed to evaluate blood loss during cesarean deliveries for twin and singleton pregnancies using both quantitative and calculated blood loss estimation methods. Moreover, we aimed to investigate the correlation between quantitative and calculated blood loss estimations across twin and singleton deliveries.

Materials and methods

Ethical approval

This retrospective study was reviewed and approved by the Ethics Committee of Tokushima University Hospital (approval number: 4447; date: November 20, 2023) and registered with the University Hospital Medical Information Network Clinical Trial Registry (UMIN000052823). The requirement for obtaining written informed consent from all patients was waived in favor of the opt-out approach. The patient data extracted for the study were anonymized. This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

Eligibility criteria

We included singleton and twin parturients who underwent elective cesarean section under spinal anesthesia at Tokushima University Hospital between May 2019 and October 2023. The study period was set based on the date our hospital adopted the current electronic anesthesia record system. The exclusion criteria were as follows: emergency cases, cesarean delivery under general anesthesia, gestational age < 34 weeks, triplet gestation, and intrauterine fetal death. We also excluded parturients who received blood transfusions after delivery from the analysis.

Data collection and outcomes

Demographic and maternal backgrounds, including gestational complications, newborn status, intraoperative data, and laboratory parameters, such as pre- and post-delivery hematocrit levels, were retrospectively collected from electronic medical records, anesthesia records, and the obstetric delivery database.

The circulating nurse recorded the quantitative blood loss estimation based on the blood volume in the graduated collector bottle and by weighing the blood-soaked textiles during the cesarean section. Amniotic fluid volume was assumed to be included in the quantitative estimation. Calculated blood loss estimation was defined as the estimated blood volume × (preoperative hematocrit level − postoperative hematocrit level)/preoperative hematocrit level, where the estimated blood volume (mL) = weight (kg) × 85 [21, 22]. Maternal blood tests were routinely performed on the day after delivery and post-delivery days 4–5 as part of the clinical protocol at our facility.

We established two outcomes for this study. First, we evaluated blood loss in cesarean deliveries for twin and singleton pregnancies. We used quantitative estimates recorded during cesarean sections and calculated estimates on the day following cesarean delivery and 4–5 days post-delivery. Second, we explored the correlation between quantitative estimates during cesarean sections and the calculated estimates on the day following the cesareans for twin and singleton deliveries.

Statistics analysis

Data are presented as means (standard deviation [SD]) or numbers (percentages). Welch's *t*-test was used to compare blood loss estimates between twin and singleton pregnancies. Furthermore, the independent effect of fetal count on blood loss was evaluated using general linear mixed model analysis, considering individual surgeons as a random effect. This analysis adjusted for potential confounding factors, such as maternal age, body mass index (BMI), placenta previa/low-lying placenta, diabetes mellitus, hypertensive disorder of pregnancy (HDP), and assisted reproductive technologies (ART). These factors were selected for analysis based on previous studies [5, 24–28]. Pearson's correlation coefficient was used to examine the relationship between quantitative and calculated blood loss estimations.

Statistical analyses were conducted using R version 4.2.3 (The R Foundation for Statistical Computing, Vienna, Austria) and EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a modified version of R

Commander designed to incorporate statistical functions frequently used in biostatistics [29]. All p-values were two-sided, and statistical significance was set at $p < 0.05$.

Results

Overall, 950 parturients underwent cesarean section at Tokushima University Hospital during the study period. Following the preset exclusion criteria, 491 parturients were excluded due to emergency nature of the cases ($n = 471$), general anesthesia use ($n = 14$), triplet pregnancies ($n = 2$), and gestational age < 34 weeks ($n = 4$). Moreover, 56 parturients, including 2 twin pregnancies and 54 singleton pregnancies, were excluded from the analysis due to blood transfusions. Consequently, 403 patients (44 twin pregnancies and 359 singleton pregnancies) were included in the analysis. The flow diagram of patient recruitment is presented in Fig. 1. Maternal, newborn, anesthetic, and operative data are presented in Table 1.

Figure 2 presents the quantitative and calculated blood loss estimates for twin and singleton pregnancies. Quantitative blood loss measured during cesarean section was significantly higher in twin pregnancies than in singleton pregnancies (1117 [440] mL vs 698 [378] mL, mean difference: 419 mL [95% confidence interval, CI: 280–558], $p < 0.001$). However, no significant difference was observed in calculated blood loss on the day following cesarean deliveries between the two groups (488 [692] mL vs 507 [522] mL, mean difference: −19 mL [95% CI: −236 to 198], $p = 0.861$). On post-delivery days 4–5, twin pregnancies exhibited a significantly higher calculated blood loss than singleton pregnancies (725 [868] mL vs 444 [565] mL, mean difference: 281 mL [95% CI: 11–551], $p = 0.041$). General linear mixed model analyses adjusted for maternal age, BMI, placenta previa/low-lying placenta, diabetes mellitus, HDP, and ART confirmed these findings (Table 2).

Figure 3 presents the distribution of individual values of quantitative blood loss measured during cesarean section and the calculated blood loss on the day following delivery. A statistically significant and moderate correlation was observed between quantitative and calculated blood loss in singleton pregnancies ($r = 0.473$ [95% CI: 0.389 to 0.550], $p < 0.001$). However, no significant correlation was observed in twin pregnancies ($r = 0.053$ [95% CI: − 0.248 to − 0.344], $p = 0.735$).

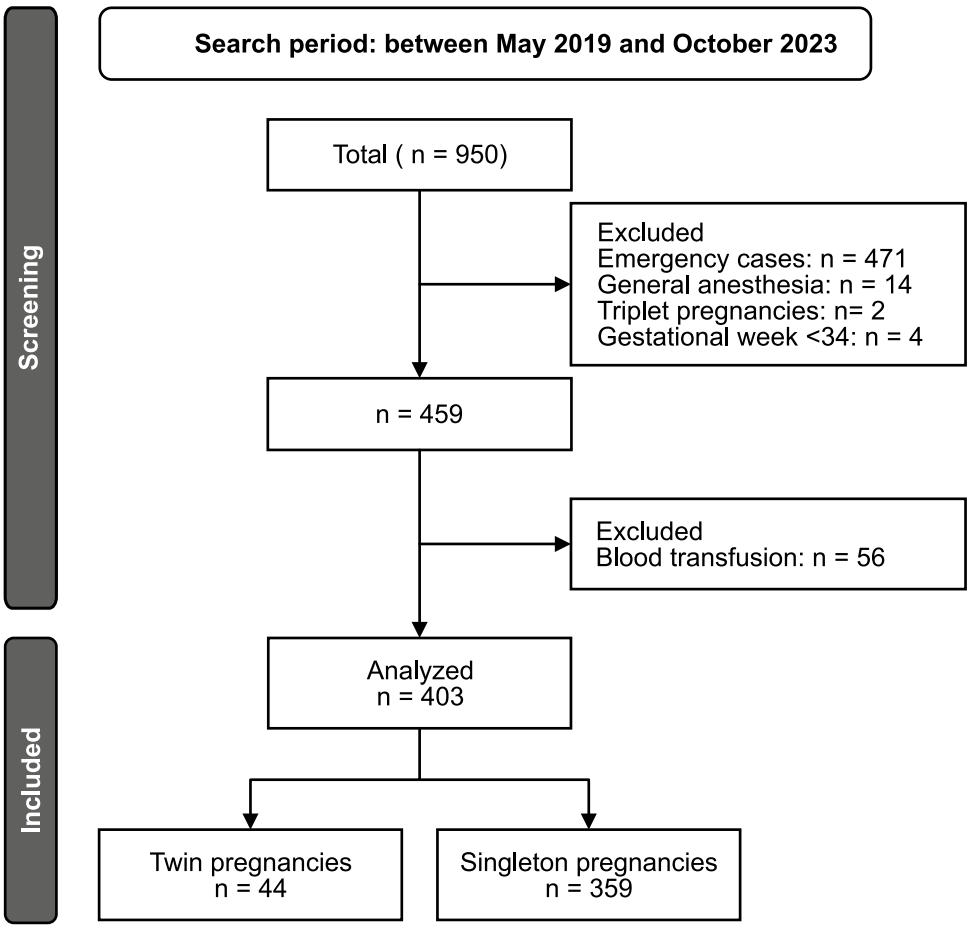

Fig. 1 Flow diagram. *n* number

Table 1 Maternal and newborn characteristics, anesthesia techniques, and operative data

	Twin ($n=44$)	Singleton ($n=359$)
Age, y	32 (5.6)	34 (4.8)
Height, cm	158.2 (4.9)	157.8 (5.6)
Weight, kg	66.1 (11.8)	62.8 (12.5)
BMI, kg/m^2	26.4 (4.1)	25.2 (4.6)
Gestational week, week	37.6 (0.8)	37.9 (0.5)
ASA-PS, no. (%)		
I	11 (25.0)	150 (41.8)
II	33 (75.0)	203 (56.5)
III	0 (0.0)	6 (1.7)
Multipara, no (%)	19 (43.2)	273 (76.0)
History of cesarean section, no (%)	1 (2.3)	237 (66.0)
ART, no (%)	6 (13.6)	60 (16.7)
HDP, no (%)	3 (6.8)	25 (7.0)
Diabetes mellitus, no (%)	5 (11.3)	44 (12.2)
Placenta previa/low-lying placenta, no (%)	0 (0)	10 (2.8)
Hemoglobin, g/dL		
Pre-delivery	10.5 (0.9)	11.2 (0.9)
Post-delivery day 1	9.5 (1.3)	10.0 (1.2)
Post-delivery day 4–5	8.9 (1.2)	9.9 (1.2)
Hematocrit, %		
Pre-delivery	31.9 (2.7)	33.5 (2.6)
Post-delivery day 1	28.9 (3.6)	30.2 (3.3)
Post-delivery day 4–5	27.4 (4.5)	30.6 (3.4)
Total fetal birth weight, g	4999 (622)	2919 (395)
Anesthesia technique		
CSEA, no. (%)	41 (93.2)	348 (96.9)
Spinal anesthesia, no. (%)	3 (6.8)	10 (2.8)
Epidural anesthesia, no. (%)	0 (0)	1 (0.3)
Operation time, min	58.4 (15.9)	66.8 (18.5)

Data are expressed as mean (standard deviation) or number (percentage)

ASA-PS American Society of Anesthesiologists physical status, *ART* assisted reproductive technology, *BMI* body mass index, *CSEA* combined spinal-epidural anesthesia, *HDP* hypertensive disorder of pregnancy

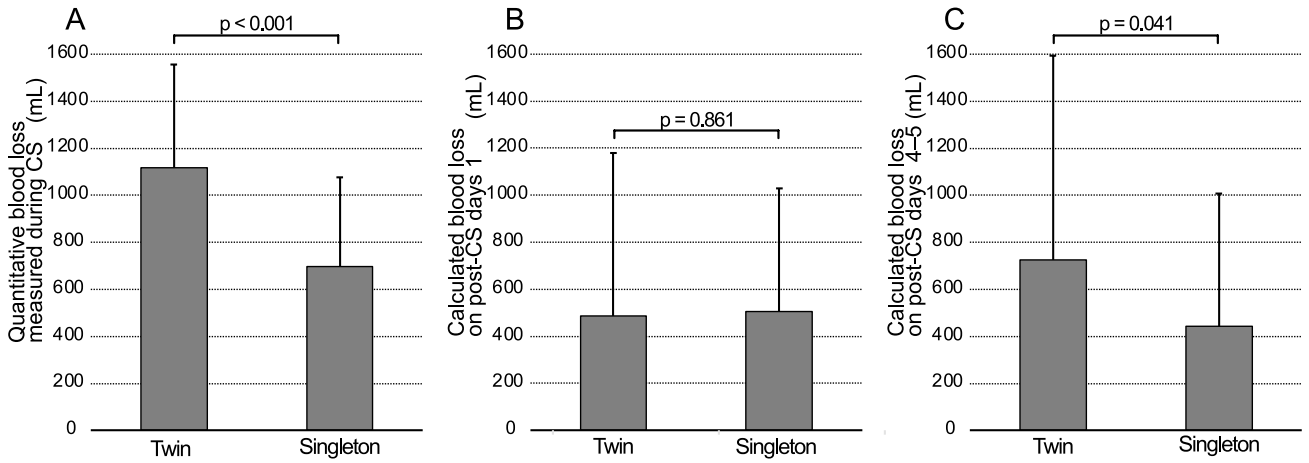

Fig. 2 Disparities in blood loss between twin and singleton pregnancies, using quantitative estimation during cesarean sections (**A**), hematocrit-based calculated estimation on the day following CS (**B**), and post-CS days 4–5 (**C**). *CS* cesarean section

Table 2 General linear mixed analysis considering individual surgeons as a random effect

Variables	Regression coefficient	95% CI	*p* value	VIF
Quantitative blood loss estimation during CS				
Twin pregnancy, binary	429.45	309.20 to 550.07	< 0.001	1.034
Maternal age, y	4.42	−3.32 to 12.19	0.268	1.128
BMI, kg/m^2	11.03	2.52 to 19.36	0.011	1.124
Placenta previa/low-lying placenta, binary	227.87	−5.66 to 550.07	0.059	1.014
Diabetes mellitus, binary	153.53	36.21 to 270.16	0.011	1.120
HDP, binary	−150.27	−294.37 to −2.18	0.044	1.033
ART, binary	118.63	16.57 to 221.54	0.025	1.112
Calculated blood loss estimation on day 1				
Twin pregnancy, binary	−29.74	−197.21 to 137.61	0.730	1.041
Maternal age, y	3.58	−7.50 to 14.64	0.530	1.134
BMI, kg/m^2	26.57	14.64 to 38.47	< 0.001	1.130
Placenta previa/low-lying placenta, binary	177.81	−152.77 to 509.17	0.297	1.013
Diabetes mellitus, binary	−38.63	−204.54 to 126.48	0.650	1.118
HDP, binary	−25.21	−228.88 to 179.25	0.810	1.029
ART, binary	233.16	85.51 to 380.81	0.002	1.116
Calculated blood loss estimation on day 4–5				
Twin pregnancy, binary	285.85	95.97 to 475.72	0.004	1.041
Maternal age, y	4.40	−8.16 to 16.96	0.496	1.134
BMI, kg/m^2	13.42	−0.10 to 26.93	0.054	1.130
Placenta previa/low-lying placenta, binary	46.74	−328.65 to 422.12	0.809	1.013
Diabetes mellitus, binary	59.15	−128.57 to 246.86	0.540	1.118
HDP, binary	−19.65	−251.09 to 211.79	0.869	1.029
ART, binary	242.30	76.62 to 407.97	0.005	1.116

ART assisted reproductive technology, *BMI* body mass index, *CI* Confidence interval, *CS* cesarean section, *HDP* hypertensive disorder of pregnancy, *VIF* variance inflation factor

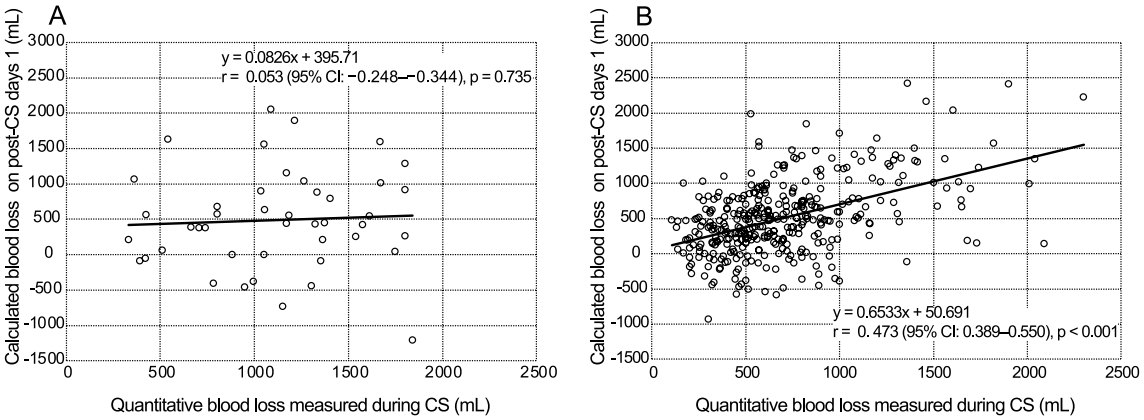

Fig. 3 Distribution of individual values of both quantitative blood loss measured during cesarean sections and calculated blood loss on the day following deliveries for twin (**A**) and singleton pregnancies (**B**). The linear regression line is presented in the graph. *CS* cesarean section

Discussion

We retrospectively evaluated blood loss during cesarean delivery for twin and singleton pregnancies using both quantitative and calculated blood loss estimation methods. Quantitative blood loss recorded during cesarean section was significantly higher in twin pregnancies than in singleton pregnancies. Nevertheless, no significant difference was observed in the hematocrit-based calculated blood loss between the two groups on the day after cesarean delivery. By post-delivery days 4–5, the calculated blood

loss was significantly higher in twin pregnancies than that in singletons.

Although the methodology of this study cannot explain the higher quantitative blood loss recorded during the cesarean section in twin pregnancies than that in singleton pregnancies, no significant difference was observed in hematocrit-based calculated blood loss between the two groups on the day following cesarean deliveries. There are two possible reasons for this. First, parturients with multiple pregnancies tend to have a higher blood volume, averaging nearly 400 mL more, along with decreased hematocrit and more frequent anemia due to dilution than singletons [30, 31]. Moreover, gestational weight gain has also been reported to be approximately 5 kg higher in twin pregnancies than that in singleton pregnancies [32]. Consequently, the loss of diluted blood volume may not affect the change in hematocrit levels as much as it would in the case of higher initial concentrations. Second, quantitative blood loss measured during cesarean section may exhibit greater inaccuracy in twin pregnancies than in singleton pregnancies. The individual amniotic fluid index for twins is similar to or slightly lower than that for singletons [33], indicating that the total amniotic fluid volume is inherently higher in twins than that in singletons. Mixing amniotic fluid in the quantitative measurements may have contributed to increased inaccuracies.

We observed a moderate correlation ($r=0.473$) between the quantitative and hematocrit-based calculated blood loss in singleton deliveries, aligning with the correlation levels reported in previous studies [13, 21]. Madar et al. reported a moderate correlation ($r=0.44$) between quantitative blood loss and hematocrit-based calculated blood loss in 8341 singleton vaginal deliveries [15]. Kahr et al. also noted a moderate correlation ($r=0.402$) between quantitative and hemoglobin-based calculated blood loss in 460 cesarean deliveries with 92.6% singleton deliveries [23]. In contrast, no significant correlation ($r=0.053$, $p=0.735$) was observed between the two evaluation methods for the twin pregnancies. Although this study involved 44 twin pregnancies, the absence of a significant correlation could be attributed to insufficient statistical power. Nonetheless, assuming a moderate correlation coefficient of $r=0.4$ and an alpha error of 0.05, this sample size should theoretically attain a power exceeding 80%. While some retrospective studies have used the quantitative method for obstetric blood loss assessment [34, 35], the accuracy of this method when used without the hematocrit-based calculated method is controversial [36]. Our study highlights potential inaccuracies in quantitative blood loss measurements during cesarean deliveries, especially in twin pregnancies.

Although no differences in the calculated blood loss between twin and singleton pregnancies were observed on the day following cesarean deliveries, the disparities widened on post-delivery days 4–5. Twin pregnancies naturally exhibit greater total fetal weight, placental mass, and total amniotic fluid volume than singleton pregnancies. Previous studies have suggested that an overstretched uterus in twin pregnancies may affect uterine contractions and result in postpartum hemorrhage, with severe cases leading to uterine atony [37, 38]. This uterine stretch may have resulted in persistent bleeding over the days following the delivery. Additionally, the larger placental size in twin pregnancies may contribute to more bleeding than that in singletons due to the increased uterine wall attachment area. Twin pregnancies (approximately 1120 g) have been reported to have almost twice the placental weight of singleton pregnancies (approximately 670 g) at 38 gestational weeks [39]. A previous study has demonstrated a positive association between placental weight and postpartum hemorrhage prevalence [40]. Our findings underscore the importance of continuous assessment to monitor potential persistent hemorrhage during the postpartum period, particularly in twin pregnancies.

This study had some limitations. First, as a retrospective analysis, the accuracy of the data collection might not have been as robust as that of prospective studies. Second, because this study was conducted at a single center in Japan, its results may not be widely generalizable owing to potential regional and demographic biases. Third, we excluded cases involving emergencies and general anesthesia, associated with a higher risk of postpartum hemorrhage [8, 41]. Patients who received blood transfusions were also excluded. This contributed to fewer cases of placenta previa or low-lying placenta with only 10 cases. Consequently, our findings do not include severe hemorrhage in high-risk groups. To better understand comprehensive cases involving severe postpartum hemorrhage, further studies including these serious scenarios are needed. Fourth, blood loss during cesarean sections may vary between inexperienced and experienced surgeons. Moreover, bias may exist owing to more complex surgeries typically handled by senior surgeons. Consequently, variations specific to individual surgeons were accounted for as random effects in a general linear mixed model. Finally, while the assessment of postpartum hemorrhage should consider both blood loss and clinical signs of cardiovascular changes post-delivery [42], this study did not include cardiovascular changes as a factor in assessing blood loss. Incorporating clinical indicators such as the shock index could provide a more comprehensive assessment of bleeding.

In conclusion, our findings indicate that the quantitative measurements obtained during cesarean section may be clinically insufficient for assessing blood loss in twin pregnancies. Therefore, integrating additional assessments, such as blood tests, is crucial for enhanced evaluation of blood loss after cesarean delivery. Moreover, continuous assessments are warranted to monitor potential persistent bleeding

in the days following cesarean delivery, particularly in twin pregnancies.

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Data availability The datasets used and analyzed during this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest All authors declare that they have no conflict of interest.

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