

Hemodynamic Changes, Serum Calcium, Magnesium Levels, and relationship with uterine contractility among postpartum women in Kabutare District Hospital in Rwanda: A Cross-Sectional Study

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Abstract

Background

Calcium and magnesium are essential electrolytes for uterine contraction, vascular regulation, and postpartum cardiovascular adaptation. The study aimed at evaluating serum calcium and magnesium levels, hemodynamic fluctuations, and their association with postpartum hemorrhage and uterine contractility in postpartum women at Kabutare District Hospital, Rwanda.

Methods

Ninety-nine postpartum women participated in a cross-sectional study carried out in a hospital setting. Venous blood samples were collected within one hour after delivery for measurement of total calcium and magnesium levels. Uterine tone, quantified blood loss, blood pressure, and pulse rate were assessed during the first 24 hours postpartum. Data were analyzed using SPSS version 25. Statistical significance was set at $p < 0.05$.

Results

Hypocalcaemia was observed in 16.2% of participants, while 8.1% had both hypocalcaemia and hypomagnesemia. Women with electrolyte abnormalities had significantly higher rates of postpartum haemorrhage than those with normal electrolyte levels (37.5% vs. 4.0%; $p = 0.003$). Serum calcium levels were significantly lower among women with a boggy uterus ($p < 0.001$). Calcium showed a negative correlation with pulse rate and a positive correlation with systolic blood pressure, whereas magnesium was positively correlated with diastolic blood pressure. Logistic regression identified hypocalcaemia (adjusted odds ratio [AOR] = 2.41), hypomagnesemia (AOR = 2.13), and boggy uterus (AOR = 8.92) as significant predictors of postpartum haemorrhage.

Conclusion

Reduced serum calcium and magnesium levels are significantly associated with impaired uterine contractility, altered postpartum hemodynamic parameters, and an increased risk of postpartum haemorrhage.

1. Introduction

Significant physiological changes that replenish the mother's electrolytes and hemodynamic balance occur during the postpartum phase after childbirth. Among the most crucial of these alterations are hemodynamic changes and electrolyte balance, particularly calcium ion (Ca^{2+}) and magnesium ion (Mg^{2+}) levels that work together to regulate cardiovascular stability, uterine contractility, and postpartum

recovery. If these parameters are disrupted, women are more vulnerable to conditions such as uterine atony, postpartum haemorrhage (PPH), hypotension, and delayed uterine involution^[1]. Postpartum haemorrhage (PPH) remains one of the leading causes of maternal morbidity and mortality worldwide and continues to represent a major public health challenge, particularly in low- and middle-income countries. According to the World Health Organization^[2] postpartum haemorrhage is defined as blood loss of ≥ 500 mL following vaginal delivery or ≥ 1000 mL following caesarean section within the first 24 hours after birth. Uterine atony accounts for approximately 70–80% of PPH cases and remains the principal cause of preventable maternal deaths. In sub-Saharan Africa, where access to timely diagnosis and emergency obstetric care is often limited, postpartum haemorrhage continues to contribute substantially to maternal mortality^[2].

Successful postpartum haemostasis depends primarily on effective uterine contraction following placental separation. Myometrial contraction is regulated through excitation–contraction coupling, in which membrane depolarization stimulates calcium influx through voltage-gated calcium channels. The resulting increase in intracellular calcium activates calmodulin and myosin light-chain kinase, initiating actin–myosin interaction and generating the contractile force required for uterine contraction^[1, 3]. Failure of this physiological process results in inadequate uterine contraction, uterine atony, and excessive postpartum bleeding. Consequently, maintenance of normal calcium homeostasis is essential for preserving uterine tone and preventing postpartum haemorrhage^[3–7].

In addition to uterine contraction, maternal cardiovascular adaptation during the postpartum period plays an important role in maintaining circulatory stability after delivery. Following placental delivery, physiological autotransfusion temporarily increases circulating blood volume. However, excessive blood loss may overwhelm these compensatory mechanisms, leading to tachycardia, hypotension, reduced tissue perfusion, and haemorrhagic shock. Since maternal compensatory responses may initially mask significant blood loss, monitoring hemodynamic parameters together with objective assessment of blood loss is essential for early recognition and management of postpartum haemorrhage^[2, 8–10].

Calcium is an essential mineral involved in several physiological processes, including excitation–contraction coupling, vascular smooth muscle function, and blood coagulation. Adequate extracellular calcium concentrations are required to maintain intracellular calcium signalling necessary for efficient myometrial contraction^[3]. Calcium ion also functions as a critical cofactor in activation of coagulation factors II, VII, IX, and X, facilitating thrombin generation and fibrin clot formation^[8, 9]. Consequently, hypocalcaemia may contribute to postpartum haemorrhage through impaired uterine contractility and defective haemostasis. Previous studies have demonstrated that women with lower serum calcium concentrations are at increased risk of uterine atony, greater postpartum blood loss, and severe postpartum haemorrhage^[10, 11].

Magnesium is the second most abundant intracellular cation and acts as a physiological calcium antagonist by regulating calcium entry into smooth muscle cells and modulating intracellular calcium

release. It influences uterine contractility through inhibition of voltage-gated calcium channels, regulation of calcium-binding proteins, and modulation of membrane excitability^[12–14]. Magnesium also contributes to cardiovascular homeostasis by regulating vascular smooth muscle tone and endothelial function^[15]. Alterations in magnesium homeostasis have been associated with impaired uterine contractility and increased postpartum blood loss. Clinical and experimental studies have reported that magnesium imbalance or prolonged magnesium sulphate exposure is associated with reduced myometrial contractility, increased quantitative blood loss, and a greater risk of postpartum haemorrhage^[1, 16, 17].

Growing evidence suggests that maternal electrolyte balance influences both uterine function and postpartum cardiovascular adaptation. Calcium deficiency has been associated with reduced vascular smooth muscle tone and altered blood pressure regulation, whereas magnesium regulates vascular resistance and myocardial excitability^[17, 18]. Despite these physiological relationships, relatively few studies have simultaneously investigated serum calcium, serum magnesium, uterine contractility, hemodynamic changes, and postpartum haemorrhage during the immediate postpartum period. Furthermore, most published studies have been conducted outside sub-Saharan Africa.

Evidence from Rwanda remains particularly scarce. Although studies conducted in East Africa have identified uterine atony, prolonged labour, grand multiparity, and inadequate uterotonic use as important risk factors for postpartum haemorrhage, these investigations did not evaluate maternal electrolyte status or its relationship with uterine contractility and hemodynamic changes^[5, 6, 7]. Consequently, important knowledge gaps remain regarding the physiological contribution of calcium and magnesium to postpartum uterine function and maternal adaptation after childbirth.

Therefore, the present study aimed to evaluate serum calcium and magnesium levels, assess postpartum hemodynamic changes, and determine their association with uterine contractility and postpartum haemorrhage among postpartum women at Kabutare District Hospital, Rwanda. The findings are expected to provide evidence supporting early identification of women at increased risk of postpartum haemorrhage and contribute to improving postpartum maternal care in Rwanda.

2. Materials and Methods

2.1 Ethical Considerations

Ethical approval

was obtained from the Institutional Review Board of the College of Medicine and Health Sciences, University of Rwanda (Reference No. CMHS/IRB/840/2025). Permission to conduct the study was granted by the administration of Kabutare District Hospital. Written informed consent was obtained from all participants before enrolment. Confidentiality was maintained through the use of coded identifiers,

and participation was voluntary. Participants were informed of their right to withdraw from the study at any stage without affecting the care they received.

2.2 Study design and population

This hospital-based cross-sectional study was conducted among postpartum women at Kabutare District Hospital, Huye District, Southern Province, Rwanda. Postpartum women who delivered at Kabutare District Hospital during the study period.

2.3 Inclusion and exclusion criteria

Women aged 17–45 years who delivered singleton term pregnancies (≥ 37 weeks of gestation) by either vaginal delivery or caesarean section and provided written informed consent were eligible for inclusion. Women with chronic renal disease, metabolic disorders, coagulation disorders, thyroid or parathyroid disease, multiple pregnancies, severe anaemia (haemoglobin < 7 g/dL), or those receiving medications known to affect calcium or magnesium metabolism were excluded. Women who had received magnesium sulphate therapy before delivery or blood transfusion prior to sample collection were also excluded.

2.4 Sample Size and Sampling Technique

The sample size for postpartum women was determined using Cochran's formula

$n_0 = Z^2 P(1-P)/e^2$ Where: $Z = 1.96$ ($Z = 1.96$ (95% confidence level)), $p = 0.5$ ($p = 0.5$ (assumed proportion for maximum variability)); $e = 0.05$ ($e = 0.05$ (margin of error)), $n_0 = (1.96)^2 \times 0.5 \times 0.5 / (0.05)^2 = 384$. Thus, the initial sample size was: $n_0 = 384$. Since the total population was 275 postpartum women, the adjusted sample size was calculated as

$n = n_0 / 1 + 383/275$ Where $N = 275$; $n = 384 / 2.3927$ $n = 161$

Only 99 women were included because some women did not meet the eligibility criteria, were discharged early, were referred to another health facility, or declined to participate.

2.5 Data Collection

Data were collected using a structured questionnaire, clinical observation checklist, and laboratory data collection form. Information on maternal age, obstetric characteristics, nutritional practices, and clinical history was obtained through participant interviews and review of medical records.

Hemodynamic parameters, including systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate, were measured using a calibrated automated digital sphygmomanometer (OMRON M6 IT, HEM-7322-E, Omron Healthcare, Japan). Measurements were obtained immediately after delivery (0 hours), and at every 4 hours, until 24 hours postpartum. Two readings were taken one minute apart, and the average value was recorded.

Uterine tone was assessed by abdominal palpation^[19] of the uterine fundus at 15 minutes, 30 minutes, 1 hour, 4 hour and then at 24 hours and classified as firm, moderate, or boggy^[20]. Quantified blood loss was determined using the gravimetric method by weighing blood-soaked materials before and after use, where 1 g weight gain was considered equivalent to 1 mL of blood loss^[20]. Blood collected in calibrated containers was added to obtain the total quantified blood loss. Postpartum haemorrhage was defined as blood loss of ≥ 500 mL following vaginal delivery or ≥ 1000 mL following caesarean section within the first 24 hours postpartum.

2.6 Laboratory analysis

Within one hour after delivery, 5 mL of venous blood was collected aseptically into plain vacutainer tubes. Blood samples were allowed to clot for 30 minutes and centrifuged at 3000 rpm for 10 minutes to obtain serum. Serum samples were stored at -20°C until analysis. Serum total calcium was measured using the COBAS chemistry analyzer (Model: cobas® c 311, Roche Diagnostics GmbH, Mannheim, Germany). Ionized calcium was not measured, and serum albumin was not available to correct total calcium for protein binding. This represents a limitation of the study, as approximately 40–50% of circulating calcium is protein-bound, and pregnancy-associated hypoalbuminemia may affect total calcium concentrations. However, total calcium remains a practical and widely available screening tool in resource-limited district hospital settings, consistent with routine clinical practice. Commercial quality-control sera were included with each analytical batch to ensure accuracy and reliability. All participants underwent spontaneous labour. None of the women in the study underwent labour induction or labour augmentation. In addition, all participants received prophylactic oxytocin as part of the hospital's routine active management of the third stage of labour. Therefore, labour induction, labour augmentation, and oxytocin use were not included as variables in the statistical analysis because there was no variation among participants.

2.7 Outcome Measures

The primary outcome measures were serum calcium and magnesium status, uterine tone, quantified blood loss, and postpartum hemodynamic changes, including systolic blood pressure, diastolic blood pressure, pulse rate postpartum haemorrhage.

2.8 Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 25.0. Continuous variables were summarized using means and standard deviations or medians and interquartile ranges, depending on data distribution, while categorical variables were presented as frequencies and percentages. Normality of continuous variables was assessed using the Shapiro–Wilk test. Associations between categorical variables were examined using the Chi-square test or Fisher's exact test where appropriate. Pearson or Spearman correlation analysis was used to evaluate relationships between serum electrolyte concentrations and hemodynamic parameters. logistic regression analysis was performed to identify predictors of postpartum haemorrhage. Variables with statistical significance were

reported as adjusted odds ratios (AORs) with 95% confidence intervals (CIs). p -value < 0.05 was considered statistically significant.

3 Results

A total of 100 postpartum women meeting the inclusion criteria were recruited for the study. One participant developed severe postpartum haemorrhage and was referred to the University Teaching Hospital of Butare (CHUB) before completion of follow-up; therefore, complete data from 99 participants were included in the final analysis.

3.1 Sociodemographic of Participants

The mean age of participants was 29.9 ± 6.1 years, and most women were aged 26–34 years (45.5%). The majority had primary education (67.8%) and were farmers (86.0%). Most participants were multigravida (G2–G4, 52.5%), multiparous (P2–P4, 48.4%), and delivered vaginally (60.6%) as shown Table 1.

3.2 Prevalence of Normal and Abnormal Calcium and Magnesium Status

The serum levels of calcium and magnesium are presented in Table 2. The majority of participants had normal calcium and magnesium levels, accounting for 75.8% ($n = 75$). Participants with low calcium only represented 16.2% ($n = 16$), while 8.1% ($n = 8$) had both low calcium and magnesium levels. No participant had isolated low magnesium levels. Serum calcium concentrations of 8.5–10.5 mg/dL were considered normal, with values < 8.5 mg/dL classified as hypocalcaemia. Serum magnesium concentrations of 1.7–2.4 mg/dL were considered normal, with values < 1.7 mg/dL classified as hypomagnesemia.

Table 1
Sociodemographic of participants

Characteristic	Category	Frequency (n)	Percentage (%)
Age (years)	17–25	28	28.2
	26–34	45	45.5
	35–42	26	26.3
Education	Primary	67	67.8
	Secondary	11	10.1
	None	22	22.1
Occupation	Farmer	86	86.0
	Other	14	14.0
Gravidity	G1	32	32.3
	G2–G4	52	52.5
	≥G5	15	15.1
Parity	P1	33	33.4
	P2–P4	48	48.4
	P5–P7	18	18.2
Number of Live Births	1	32	32.3
	2–4	57	57.5
	≥ 5	10	10.1
Mode of Delivery	Vaginal	60	60.6
	Caesarean Section	39	39.4
N = 99; G = gravidity; P = parity; ≥ = greater than or equal to			

Table 2
Calcium and Magnesium Status in the Study Population

Electrolyte Status	Definition / Reference Values	Frequency (n)	Percentage (%)
Normal Ca and Mg	Calcium: 8.5–10.5 mg/dL; Magnesium: 1.7–2.4 mg/dL	75	75.8
Low Ca only	Calcium < 8.5 mg/dL; Magnesium: 1.7–2.4 mg/dL	16	16.2
Low Mg only	Calcium: 8.5–10.5 mg/dL; Magnesium < 1.7 mg/dL	0	0.0
Both low Ca and Mg	Calcium < 8.5 mg/dL; Magnesium < 1.7 mg/dL	8	8.1
Total	—	99	100

3.3 Association between electrolyte status and postpartum haemorrhage

Postpartum haemorrhage occurred in 9 women (9.1%). Women with combined hypocalcaemia and hypomagnesaemia had the highest proportion of postpartum haemorrhage (37.5%) compared with women with isolated hypocalcaemia (18.8%) and women with normal electrolyte levels (4.0%). The association between electrolyte status and postpartum haemorrhage was statistically significant (Fisher's exact test, $p = 0.003$) as shown in Table 3.

3.4 Comparison of Calcium and Magnesium Levels between PPH and Non-PPH Groups

Women who developed postpartum haemorrhage had significantly lower mean calcium levels (7.7 ± 0.97 mg/dL) compared to women without PPH (9.0 ± 0.89 mg/dL). Similarly, serum magnesium levels were lower among women with PPH (1.8 ± 0.1 mg/dL) compared to the non-PPH group (2.2 ± 0.22 mg/dL). These differences were statistically significant ($P < 0.001$), suggesting that reduced calcium and magnesium levels were associated with postpartum haemorrhage is displayed in Table 4.

Table 3
Association between electrolyte status and postpartum haemorrhage

Electrolyte status	PPH n (%)	No PPH n (%)	<i>p-value</i>
Normal calcium and magnesium	3 (4.0)	72 (96.0)	
Low calcium only	3 (18.8)	13 (81.2)	
Both low calcium and magnesium	3 (37.5)	5 (62.5)	0.003
*Fisher's Exact Test			

Table 4
Comparison of Serum Calcium and Magnesium Levels Between Women with and Without Postpartum Haemorrhage

Variable	PPH (n = 9) Mean $\pm$ SD	Non-PPH (n = 90) Mean $\pm$ SD	<i>t-value</i>	df	<i>p-value</i>	95% CI
Calcium (Ca) mg/dL	7.7 $\pm$ 0.97	9.0 $\pm$ 0.89	4.56	97	< 0.001	[0.73, 1.87]
Magnesium (Mg) mg/dL	1.8 $\pm$ 0.1	2.2 $\pm$ 0.22	5.49	97	< 0.001	[0.26, 0.54]

3.5 Comparison of serum calcium and magnesium by uterine tone

Women with firm uterine tone had significantly higher calcium and magnesium levels compared to women with boggy uterus both at 15 minutes and at 24 hours postpartum. These findings indicate that lower electrolyte levels were associated with poor uterine tone (Table 5).

3.6 Uterine tone at 15 minutes postpartum: a critical predictor of blood loss and postpartum haemorrhage

Women with boggy uterine tone at 15 minutes postpartum experienced more than double the blood loss compared to those with firm uterine tone (733.0 mL vs 321.4 mL). Notably, zero postpartum haemorrhage (PPH) cases occurred among women with firm uterine tone, whereas 22.5% of women with boggy uterus developed PPH, therefore accounting for all 9 PPH cases in the study.

A strong association with mode of delivery was observed as 93.2% of women with firm uterine tone delivered vaginally, while 87.5% of women with boggy uterus underwent caesarean section (Fig. 1). This highlights the clinical link between caesarean delivery, uterine atony, and elevated risks of excessive blood loss and PPH.

Table 5
Comparison of Serum Calcium and Magnesium by Uterine Tone

Time Point	Variable	Firm Uterus Mean $\pm$ SD	Boggy Uterus Mean $\pm$ SD	Test	<i>p</i> -value
15 Minutes	Calcium (mg/dL)	9.20 $\pm$ 0.55	8.36 $\pm$ 0.90	t-test	< 0.001
	Magnesium (mg/dL)	2.21 $\pm$ 0.15	2.01 $\pm$ 0.28	t-test	< 0.001
24 Hours	Calcium (mg/dL)	8.95 $\pm$ 0.75	7.00 $\pm$ 0.85	Mann-Whitney U	< 0.01
	Magnesium (mg/dL)	2.15 $\pm$ 0.20	1.75 $\pm$ 0.15	Mann-Whitney U	< 0.01
*Data are presented as Mean $\pm$ Standard Deviation. Uterine tone assessed at 24 hours postpartum (Firm = adequate uterine contraction; Boggy = uterine atony), *Mann–Whitney U test was used due to small sample size in boggy group (n = 2) and non-normal data distribution; SD = Standard Deviation; mg/dL = milligrams per deciliter; U = Mann–Whitney U statistic					

3.7 Association Between Electrolytes and Hemodynamics

Serum calcium was negatively correlated with pulse rate ($r = -0.42$, $p < 0.001$) and positively correlated with systolic blood pressure ($r = 0.28$, $p = 0.005$). Serum magnesium showed a negative correlation with pulse rate ($r = -0.36$, $p < 0.001$) and a positive correlation with diastolic blood pressure ($r = 0.25$, $p = 0.010$) as shown in Table 6.

Table 6
Association between electrolytes and haemodynamic parameters

Variable Pair	Correlation (<i>r</i>)	<i>p</i> -value	Clinical Significance
Calcium vs. Pulse	-0.42	< 0.001	Significant Negative Correlation
Magnesium vs. Pulse	-0.36	< 0.001	Significant Negative Correlation
Calcium vs. SBP	+ 0.28	0.005	Significant Positive Correlation
Magnesium vs. DBP	+ 0.25	0.010	Significant Positive Correlation

3.8 Uterine tone progression and hemodynamic parameters over 24 hours

The variations in uterine tone categories and hemodynamic measures throughout the 24 hours after birth are shown in Fig. 2. A significant percentage of participants had moderate and boggy uterine tone at baseline (Fig. 2A), but during the course of the observation period, the percentage of patients with firm uterine tone gradually increased. Nearly all subjects showed firm uterine tone after 24 hours, but incidences of moderate and boggy tone significantly decreased. In addition, systolic and diastolic blood pressure (Fig. 2B) as well as heart rate were very steady over the monitoring period, with only slight

physiological variations recorded (Supplementary table 1). These findings imply progressive improvement in uterine contractility without considerable hemodynamic instability.

3.9 Logistic Regression for Postpartum Hemorrhage

Multivariable logistic regression identified hypocalcaemia (AOR = 2.41; 95% CI: 1.58–3.67; $p < 0.001$), hypomagnesaemia (AOR = 2.13; 95% CI: 1.39–3.26; $p < 0.001$), and boggy uterine tone at 15 minutes (AOR = 8.92; 95% CI: 3.12–25.48; $p < 0.001$) as independent predictors of postpartum haemorrhage. Caesarean section and parity greater than three were not independently associated with postpartum haemorrhage as shown in Table 7 (Supplementary table 2, 3).

Table 7
Logistic regression for predictors of postpartum haemorrhage

Predictor	Adjusted Odds Ratio (AOR)	95% Confidence Interval	p-value
Hypocalcaemia	2.41	1.58–3.67	< 0.001
Hypomagnesemia	2.13	1.39–3.26	< 0.001
Boggy Uterus (15 min)	8.92	3.12–25.48	< 0.001
Caesarean Section	1.78	0.95–3.34	0.070
Parity > 3	1.45	0.82–2.56	0.200

Due to the limited number of postpartum haemorrhage events ($n = 9$), regression estimates were considered exploratory and interpreted cautiously.

4. Discussion

In the present study, women who developed postpartum haemorrhage had significantly lower mean serum calcium (7.7 ± 0.97 mg/dL vs. 9.0 ± 0.89 mg/dL, $p < 0.001$) and magnesium concentrations (1.8 ± 0.10 mg/dL vs. 2.2 ± 0.22 mg/dL, $p < 0.001$) than women without postpartum haemorrhage. Moreover, the association between electrolyte status and postpartum haemorrhage was statistically significant, with women presenting combined hypocalcaemia and hypomagnesemia experiencing the highest incidence of postpartum haemorrhage. These findings are physiologically plausible because calcium is essential for excitation–contraction coupling in uterine smooth muscle and activation of the coagulation cascade, while magnesium regulates calcium transport, membrane excitability, and myometrial contractility. Consequently, deficiencies of these electrolytes may impair uterine contraction and haemostasis, thereby increasing the risk of excessive postpartum bleeding [3, 4, 16].

The present findings are consistent with previous studies that reported significantly lower maternal calcium concentrations among women with postpartum haemorrhage [10, 11]. Similarly, Badran et al. [21] and Dhillon et al. [22] demonstrated that disturbances in magnesium homeostasis were associated with impaired uterine contractility and increased postpartum blood loss. Collectively, these findings support

the hypothesis that maternal calcium and magnesium deficiencies contribute to uterine atony and postpartum haemorrhage and suggest that assessment of maternal electrolyte status may facilitate early identification of women at increased risk of postpartum haemorrhage

In the present study, women with a boggy uterus had significantly lower serum calcium and magnesium concentrations than those with a firm uterus at both 15 minutes and 24 hours postpartum. These findings indicate that reduced maternal calcium and magnesium levels are associated with impaired uterine contractility during the immediate postpartum period. Calcium plays a central role in myometrial excitation–contraction coupling by activating the calcium–calmodulin–myosin light chain kinase pathway, whereas magnesium regulates calcium influx and membrane excitability, ensuring coordinated uterine contractions^[3, 14].

The present findings are consistent with those of Miller et al.^[1] who demonstrated that impaired calcium signalling reduces myometrial contractility and increases the risk of uterine atony. Alterations in magnesium homeostasis has been associated with reduced uterine contractility and greater postpartum blood loss^[21, 22]. These findings support the important physiological role of calcium and magnesium in maintaining adequate postpartum uterine tone.

The present study demonstrated statistically significant associations between maternal electrolyte concentrations and postpartum hemodynamic parameters. Serum calcium was negatively correlated with pulse rate and positively correlated with systolic blood pressure, while serum magnesium showed a negative correlation with pulse rate and a positive correlation with diastolic blood pressure. These findings suggest that lower electrolyte concentrations may contribute to compensatory tachycardia and reduced vascular tone following childbirth. Calcium is essential for myocardial contractility and vascular smooth muscle contraction, whereas magnesium regulates vascular resistance and endothelial function and cardiovascular changes that take place after childbirth may be due to postpartum auto transfusion raises venous return, preload, stroke volume, and cardiac output after placental delivery and uterine contraction. This causes a brief spike in blood pressure and heart rate before cardiovascular balance is restored^[9]. Calcium and magnesium ions play important role in the vascular contractility of smooth muscle cells in the cardiovascular system. It has been reported that maternal cardiovascular adaptation during the postpartum period depends on adequate vascular and myocardial function^[10]. Together, these findings suggest that electrolyte disturbances may influence maternal hemodynamic stability during the early postpartum period.

In the present study, women with a boggy uterus at 15 minutes postpartum experienced more than twice the mean quantified blood loss of those with a firm uterus (733.0 mL vs. 321.4 mL), and all postpartum haemorrhage cases occurred among women with a boggy uterus. Furthermore, boggy uterine tone was the strongest independent predictor of postpartum haemorrhage. These findings suggest that uterine atony remains the principal mechanism underlying excessive postpartum bleeding. The present findings agree with reports that identify uterine atony as the leading cause of postpartum haemorrhage worldwide^[23]. It is reported that impaired myometrial contractility substantially increases postpartum

blood loss ^[24]. These findings emphasize the importance of early postpartum assessment of uterine tone for timely identification and management of women at risk of postpartum haemorrhage.

In the present study, the strong statistical association observed between boggy uterine tone at 15 minutes postpartum and subsequent blood loss underscores the critical importance of early clinical evaluation. Notably, all nine cases of postpartum haemorrhage occurred among women with a boggy uterus at 15 minutes, whereas no case occurred among those with firm uterine tone. Furthermore, an interesting clinical pattern emerged regarding the mode of delivery. Women that had undergone caesarean delivery (87.5%) had a boggy uterus compared to only 6.8% among those with a firm uterus. Caesarean delivery involves uterine incision, altered myometrial mechanics, exposure to anaesthetic agents, and often prolonged labour prior to surgery all of which can impair postoperative uterine contractility. These observations highlight that assessment of uterine tone within the immediate postpartum period (specifically at 15 minutes post-delivery) provides a vital prognostic window. When combined with baseline screening for serum calcium and magnesium levels, early identification of uterine atony allows clinical staff to initiate active management such as uterine massage and second-line uterotonic administration before hemodynamically significant haemorrhage develops.

Multivariable logistic regression demonstrated that hypocalcaemia, hypomagnesemia, and boggy uterine tone were significant independent predictors of postpartum haemorrhage, whereas caesarean delivery and parity greater than three were not statistically significant predictors after adjustment. These findings indicate that maternal electrolyte status contributes to postpartum haemorrhage independently of conventional obstetric risk factors. The observed associations are physiologically plausible because calcium and magnesium regulate uterine contractility, while a boggy uterus directly reflects ineffective postpartum myometrial contraction. These findings support previous studies^[10, 11, 16] which identified reduced calcium and altered magnesium homeostasis as important contributors to postpartum haemorrhage. Collectively, these results suggest that assessment of maternal electrolyte status, together with routine evaluation of uterine tone, may improve early identification of women at increased risk of postpartum haemorrhage, particularly in low-resource settings. Due to the low number of PPH events (n = 9), multivariable logistic regression analysis was subject to potential model overfitting. Adjusted Odds Ratios should be interpreted as exploratory estimates and require confirmation in larger cohorts.

The findings of this study suggest that maternal calcium and magnesium status may play an important role in postpartum uterine function, blood loss regulation, and maternal hemodynamic stability. The significant association between reduced electrolyte levels, impaired uterine contractility, and postpartum haemorrhage highlights the potential value of considering electrolyte status as an additional factor in postpartum risk assessment. Early identification of women with poor uterine tone, electrolyte abnormalities may improve prevention and timely management of postpartum haemorrhage, particularly in resource-limited settings. These findings also support the need for further research to determine whether improving maternal calcium and magnesium status through nutritional interventions or supplementation could reduce the risk of postpartum complications.

This study has several strengths. First, it addresses an important knowledge gap regarding the role of maternal electrolytes in postpartum haemorrhage in Rwanda, a topic that has not been previously investigated in this setting. Second, we used objective, standardized laboratory methods (COBAS chemistry analyzer) with quality control procedures to measure serum calcium and magnesium. Third, blood loss was quantified using the gravimetric method rather than visual estimation, reducing measurement bias and improving the accuracy of postpartum haemorrhage diagnosis. Fourth, serial measurements of hemodynamic parameters were obtained at standardized time points, allowing assessment of temporal trends in the early postpartum period. Fifth, we included comprehensive clinical data on uterine tone assessed at multiple time points, providing insights into the progression of uterine contractility after delivery.

There are few limitations of this study. It was limited by its single-centre design, relatively small sample size, and cross-sectional nature, which restrict causal inference and generalizability. Because the study was conducted at a single district hospital, the findings may not be generalizable to all postpartum women in Rwanda. Serum calcium and magnesium were measured at a single time point, and ionized calcium was not assessed. Additionally, serum albumin was not measured to calculate corrected calcium levels; therefore, the potential influence of gestational hemodilution or hypoalbuminemia on total calcium concentrations and hypocalcemia rates cannot be completely excluded. Although ionized calcium is the biologically active form, total serum calcium remains a practical and cost-effective screening method in resource-limited settings, reflecting routine clinical practice at district-level facilities. Furthermore, only nine postpartum haemorrhage events occurred, which may have reduced the stability of the multivariable logistic regression model and increased the risk of overfitting. Although several potential confounding factors, including maternal age, body mass index, haemoglobin concentration, duration of labour, nutritional status, parity, and previous postpartum haemorrhage, were collected, residual confounding cannot be completely excluded.

5. Conclusion

The present study demonstrates that low maternal serum calcium and magnesium levels are significantly associated with postpartum haemorrhage, reduced uterine contractility, and altered postpartum hemodynamic responses among women delivering at Kabutare District Hospital, Rwanda. Hypocalcaemia, hypomagnesaemia, and boggy uterine tone were identified as important predictors of postpartum haemorrhage, emphasizing the physiological importance of these electrolytes in maintaining effective myometrial contraction and postpartum haemostasis. These findings suggest that maternal electrolyte status, together with early assessment of uterine tone and blood loss, may contribute to improved identification and management of women at risk of postpartum haemorrhage. However, these findings should be interpreted cautiously and validated through larger multicentre studies before they are generalized to the wider Rwandan population.

Abbreviations

AOR
Adjusted Odds Ratio
BMI
Body Mass Index
Ca
Calcium
 Ca^{2+}
Calcium Ion
Cl
Confidence Interval
CHUB
University Teaching Hospital of Butare (Centre Hospitalier Universitaire de Butare)
COBAS
Commercially Available Biochemistry Analysis System (COBAS Chemistry Analyzer)
CMHS
College of Medicine and Health Sciences
DBP
Diastolic Blood Pressure
G
Gravidity
G1
Primigravida
G2–G4
Gravidity Two to Four
IQR
Interquartile Range
IRB
Institutional Review Board
Mg
Magnesium
 Mg^{2+}
Magnesium Ion
MLCK
Myosin Light Chain Kinase
OMRON
Omron Healthcare Blood Pressure Monitor
OR
Odds Ratio
P
Parity

PPH
Postpartum Haemorrhage
QBL
Quantified Blood Loss
SBP
Systolic Blood Pressure
SPSS
Statistical Package for the Social Sciences
UR
University of Rwanda
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from The University of Rwanda's IRB and the Rwanda National Ethics Committee with Reference number: CMHS/IRB/840/2025. All participants provided verbal informed consent prior to participation. All methods were carried out in accordance with relevant guidelines and regulations. Also, participants were able to leave at any time without consequence, and confidentiality was upheld.

Use of Artificial Intelligence

Generative artificial intelligence tools were not used in the drafting or writing of this manuscript.

Consent for publication

Not applicable.

Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

All authors declare no conflict of interest.

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Author contributions

NG conceptualized and designed the study, collected the data, and drafted the manuscript. **OO** contributed to the development of the study concept, supervised the project, and reviewed the manuscript. **EDE** contributed to data interpretation and critically reviewed the manuscript for important intellectual content. **DCI** contributed to the literature review, data interpretation, and revision of the manuscript. **EJA** contributed to the interpretation of the study findings and critically reviewed the manuscript. **DUO** supervised the project and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Figures

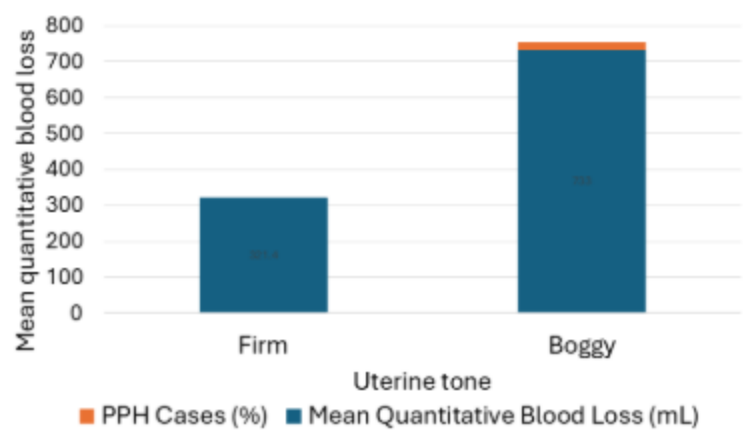


Figure 1

Association between uterine tone at 15 minutes postpartum and mean quantitative blood loss with postpartum haemorrhage cases

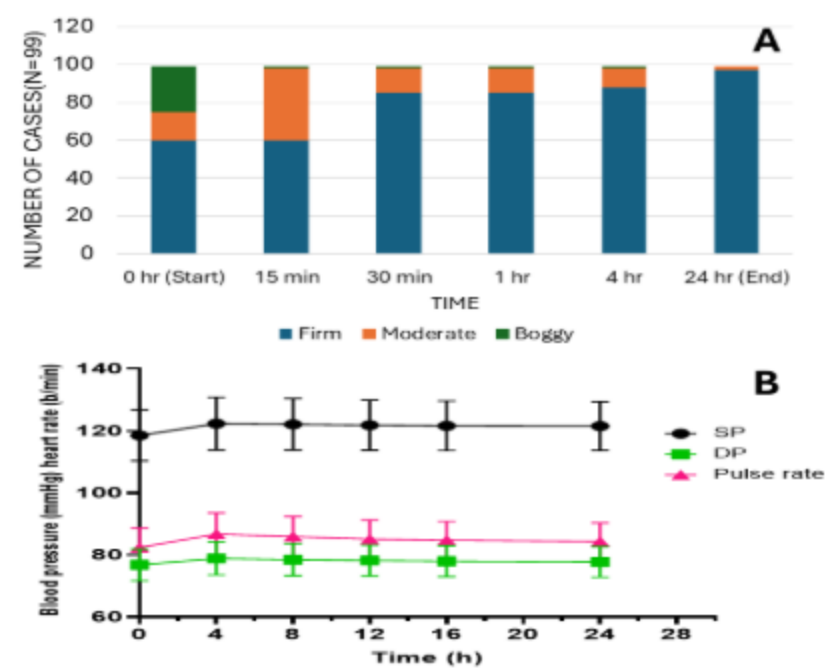


Figure 2

Uterine tone progression and hemodynamic parameters over 24 hours

Supplementary Files

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