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Original Article

Efficacy of Carbetocin in Prevention of Postpartum Hemorrhage Compared to Oxytocin Following Cesarean Section

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ABSTRACT

Background: Postpartum hemorrhage (PPH) remains a major cause of maternal morbidity and mortality globally, particularly following cesarean section. Although Oxytocin is the conventional uterotonic for PPH prevention, its short half-life and need for continuous infusion may limit effectiveness. Carbetocin, a long-acting Oxytocin analogue, offers sustained uterotonic action with single-dose administration. This study aimed to compare the efficacy and safety of Carbetocin with Oxytocin in the prevention of PPH following cesarean section.

Methods: A prospective, observational case–control study was conducted at the Department of Obstetrics and Gynaecology, MKCG Medical College and Hospital, Berhampur, Odisha, between 2023 and 2025. A total of 240 women at high risk for PPH undergoing cesarean section were enrolled and divided into two groups: Carbetocin (n = 120) and Oxytocin (n = 120). Demographic, obstetric, and hemodynamic data were collected. Primary outcomes included estimated blood loss and the need for additional uterotonics, while secondary outcomes assessed blood transfusion requirement, hemodynamic changes, and adverse drug reactions. Statistical analysis was performed using independent t-tests and chi-square tests, with $p < 0.05$ considered significant.

Results: Both groups were comparable in baseline characteristics. Carbetocin administration resulted in significantly lower intraoperative blood loss and reduced need for additional uterotonics compared to Oxytocin ($p < 0.001$). Fewer women in the Carbetocin group required blood transfusion or surgical interventions for hemorrhage control. Adverse effects such as nausea, vomiting, and diarrhea were mild and similar across groups; however, shivering was significantly more common with Oxytocin ($p = 0.006$). Hemodynamic parameters and postoperative hemoglobin levels remained stable and comparable between groups.

Conclusion: Carbetocin demonstrated superior efficacy to Oxytocin in preventing postpartum hemorrhage after cesarean section by reducing blood loss, minimizing the need for additional uterotonics, and maintaining favorable safety and hemodynamic profiles. Given its prolonged duration of action, single-dose administration, and room-temperature stability, Carbetocin represents an effective and practical alternative to Oxytocin for PPH prophylaxis, particularly beneficial in resource-limited settings.

Keywords: *Carbetocin, Oxytocin, Postpartum Hemorrhage, Cesarean Section, Maternal Health, Uterotonic Agents.*

INTRODUCTION

Postpartum hemorrhage (PPH) is one of the most critical obstetric emergencies and remains a leading cause of maternal morbidity and mortality worldwide. According to the World Health Organization (WHO, 2018), PPH accounts for approximately 27% of maternal deaths globally, with a disproportionate burden seen in low- and middle-income countries (LMICs) where access to timely obstetric interventions is limited. PPH is clinically defined as blood loss

exceeding 500 mL after vaginal delivery or more than 1000 mL following cesarean section, though actual blood loss is often underestimated due to subjective visual assessment (Stafford et al., 2008). The condition can rapidly lead to hypovolemic shock, disseminated intravascular coagulation (DIC), and maternal death if not promptly managed (Say et al., 2014).

With the rising rate of cesarean deliveries, the global risk of PPH has increased. Women undergoing lower segment cesarean section (LSCS) are two to three times more likely to develop PPH compared to those delivering vaginally (Committee on Practice Bulletins–Obstetrics, 2017). This elevated risk is attributed to factors such as uterine atony, placental abnormalities (placenta previa or accreta), and surgical trauma. Consequently, the prevention of PPH has become a top priority in obstetric practice, emphasizing the use of effective uterotonic agents immediately after childbirth.

Oxytocin, a synthetic analogue of the endogenous hormone secreted by the posterior pituitary gland, is the most widely used uterotonic agent and remains the WHO-recommended first-line therapy for PPH prevention. It acts on uterine smooth muscle to produce rhythmic contractions that promote placental separation and minimize blood loss (Tunçalp et al., 2013). However, oxytocin's clinical utility is limited by its short half-life (3–5 minutes), necessitating repeated dosing or continuous intravenous infusion to sustain its effect. Moreover, oxytocin is thermolabile and requires cold-chain storage, making its use challenging in resource-limited settings with unreliable refrigeration (Chao & McCormack, 2019).

Carbetocin, a long-acting synthetic oxytocin analogue, has emerged as a promising alternative for PPH prevention. Pharmacologically, it binds to oxytocin receptors in the myometrium but exhibits greater resistance to enzymatic degradation, resulting in a prolonged uterotonic effect lasting up to 60 minutes with a single dose (Sweeney et al., 1990). The development of a heat-stable formulation of Carbetocin further enhances its suitability for use in LMICs where maintaining cold-chain storage is often impractical. The landmark CHAMPION trial (WHO, 2018) demonstrated that heat-stable Carbetocin was non-inferior to oxytocin in preventing PPH after vaginal deliveries, suggesting its potential for broader obstetric applications, including cesarean sections.

Several clinical trials have compared Carbetocin and Oxytocin in cesarean deliveries, yielding mixed findings. Studies by Attilakos et al. (2010) and Borruto et al. (2009) reported significantly reduced blood loss and a lower need for additional uterotonics with Carbetocin, while others such as Nucci et al. (2016) and Razali et al. (2016) found comparable efficacy between the two drugs. Hemodynamic stability and adverse effect profiles have also been similar in both groups, although Carbetocin has been associated with fewer thermogenic reactions such as shivering (De Bonis et al., 2012; Moertl et al., 2011).

Given these inconsistencies, there is a pressing need for further evaluation of Carbetocin's efficacy in preventing PPH following cesarean delivery. The present study was therefore designed to compare the prophylactic efficacy and safety of Carbetocin versus Oxytocin in women undergoing cesarean section at high risk of PPH. By assessing parameters such as intraoperative blood loss, the need for additional uterotonics, transfusion rates, and hemodynamic stability, this study aims to provide robust clinical evidence to inform future obstetric protocols and potentially support the wider adoption of Carbetocin as a first-line uterotonic agent for PPH prevention.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational case–control study titled *"To Study the Efficacy of Carbetocin in Prevention of Postpartum Hemorrhage Compared to Oxytocin Following Cesarean Section"* was carried out between 2022 and 2025 in the Department of Obstetrics and Gynaecology, MKCG Medical College and Hospital, Berhampur, Odisha. The institution is a tertiary-care referral center catering to a large population from southern Odisha and neighboring regions, offering comprehensive obstetric services that make it ideal for evaluating uterotonic agents in the prevention of postpartum hemorrhage (PPH) (Su et al., 2012; Gallos et al., 2018).

Study Population

Participants included full-term pregnant women undergoing elective or emergency lower-segment cesarean section (LSCS) who were identified as being at high risk for PPH. Recruitment occurred between 2023 and 2025 after obtaining informed consent. The study followed the **STROBE** guidelines for observational studies to ensure reporting quality and methodological transparency (Von Elm et al., 2007).

Inclusion Criteria

Women were eligible if they had full-term pregnancies and met at least one high-risk criterion for PPH such as grand multiparity (≥ 5 deliveries), polyhydramnios, fetal macrosomia, anemia, multifetal pregnancy, prolonged labor, or uterine over-distension (Rath, 2009; El Behery et al., 2016). Written informed consent was obtained from each participant before enrollment.

Exclusion Criteria
Women were excluded if they had conditions that could alter uterine contractility or complicate blood-loss estimation, including uterine fibroids, hypertensive disorders, cardiac disease, chronic liver or renal pathologies, endocrine abnormalities, or coagulopathies such as disseminated intravascular coagulation (DIC), thrombocytopenia, or hypofibrinogenemia (Moertl et al., 2011). Patients with placental abnormalities (placenta accreta spectrum, placental abruption) or requiring a classical (vertical) uterine incision were also excluded.

Sampling Method
A purposive, non-randomized sampling approach was used. Eligible participants were allocated to one of two groups depending on the uterotonic drug used during surgery as part of standard clinical care: the **carbetocin group** or the **oxytocin group**. This pragmatic approach reflected real-world practice and facilitated comparison between the two most widely employed uterotonics (Heesen et al., 2019).

Sample Size Calculation
The sample size was calculated using the standard formula for comparing two proportions in case–control studies. Based on the trial by **Attilakos et al. (2010)**, the incidence of PPH was assumed to be 20 % in the oxytocin group ($P_1 = 0.20$) and 10 % in the carbetocin group ($P_2 = 0.10$). With a 95 % confidence level ($Z\alpha/2 = 1.96$) and 80 % power ($Z\beta = 0.84$), the minimum required sample was 98 participants per group. Allowing for 20 % attrition, the final sample size was rounded to 120 per group (total = 240 participants) to maintain adequate statistical power.

Ethical Considerations
Ethical clearance was obtained from the **Institutional Ethics Committee** of MKCG Medical College and Hospital, Berhampur, Odisha. Participants were assured of confidentiality and their right to withdraw from the study at any stage without affecting their ongoing treatment. The study adhered to the ethical principles outlined in the **Declaration of Helsinki**.

Data Collection Procedure
After ethics approval and consent, data were prospectively collected using a structured case record form. Baseline information such as age, parity, body-mass index (BMI), socioeconomic status, and obstetric history were recorded. Intraoperative parameters included type of uterotonic used, estimated blood loss (EBL), and any complications. Blood loss was quantified by **direct visual estimation** and the **gravimetric method**, which are validated techniques for assessing intraoperative hemorrhage (Dahlke et al., 2015). Hemodynamic parameters (blood pressure and heart rate) were measured before administration of the study drug and at skin closure. The need for additional uterotonics (e.g., misoprostol, methylergometrine), blood transfusion, or ICU admission was documented. Postoperative follow-up continued for 24 hours to monitor adverse drug reactions such as hypotension, nausea, vomiting, flushing, or tachycardia (Rath, 2009; Ruysen et al., 2021).

Data Analysis
Data were entered in **Microsoft Excel** and analyzed using **Jamovi software** (Version 2.4.2) in collaboration with the Department of Community Medicine, MKCG Medical College. Graphs and visualizations were generated using Jamovi, Excel, and Python for enhanced data clarity and reproducibility (Hawley et al., 2017).

Statistical Analysis
Descriptive statistics such as mean ± standard deviation (SD) and percentages were computed for demographic and clinical variables. Between-group comparisons were performed using the **independent t-test** for continuous variables and the **Chi-square (χ^2) test** for categorical variables. A p-value < 0.05 was considered statistically significant (Gallos et al., 2018). All analyses followed contemporary obstetric research reporting standards and ensured transparency in methodology.

RESULTS
Age Distribution of Participants (Years)
The mean age of participants in the Carbetocin group (27.3 ± 7.64 years) was slightly lower than in the Oxytocin group (29.7 ± 7.90 years), indicating comparable reproductive-age populations across groups, thereby minimizing age-related confounding in uterine contractility or PPH risk.

Table 1. Age distribution of participants (years)

Group	N	Mean	SD
Carbetocin	120	27.3	7.64
Oxytocin	120	29.7	7.90

Age-Group Distribution of Study Participants

Most participants were aged 21–30 years in both groups, representing the predominant reproductive age range. The distribution pattern confirms that younger women constituted the majority, aligning with the typical cesarean delivery demographic profile.

Table 2. Age-group distribution (%)

Age group (yrs)	Carbetocin n (%)	Oxytocin n (%)	Total n (%)
≤ 20	18 (15.0)	15 (12.5)	33 (13.8)
21–25	44 (36.7)	26 (21.7)	70 (29.2)
26–30	31 (25.8)	31 (25.8)	62 (25.8)
31–35	10 (8.3)	15 (12.5)	25 (10.4)
36–40	5 (4.2)	18 (15.0)	23 (9.6)
41–45	4 (3.3)	15 (12.5)	19 (7.9)
> 45	8 (6.7)	0 (0.0)	8 (3.3)

Comparison of Height and Weight Between Study Groups

The mean height and weight were similar across groups (151 cm and 69 kg), suggesting both groups were anthropometrically comparable. This homogeneity indicates that variations in body habitus were unlikely to influence blood loss outcomes.

Table 3. Height and weight comparison

Variable	Group	N	Mean	SD
Height (cm)	Carbetocin	120	151.7	4.56
	Oxytocin	120	151.6	4.19
Weight (kg)	Carbetocin	120	70.4	10.32
	Oxytocin	120	68.2	9.94

Parity Distribution of Participants

Parity distribution showed most participants were primiparous (Carbetocin 65%, Oxytocin 55.8%). The Chi-square test ($p = 0.270$) confirmed no significant difference, ensuring equal parity-related uterine tone factors in both cohorts.

Table 4. Parity distribution ($\chi^2 = 2.620$, df = 2, $p = 0.270$)

Group	Grand multi n (%)	Multi n (%)	Primi n (%)
Carbetocin	5 (4.2)	37 (30.8)	78 (65.0)
Oxytocin	4 (3.3)	49 (40.8)	67 (55.8)

3.5.Comparison of Booking Status Between Groups

Most women were booked cases who received antenatal care (≈75% in both groups). The near-identical proportions ($p = 0.881$) imply similar obstetric risk preparedness, reducing care-related bias in PPH prevention outcomes.

Table 5. Booking status ($\chi^2 = 0.022$, df = 1, $p = 0.881$)

Group	Booked n (%)	Unbooked n (%)
Carbetocin	90 (75.0)	30 (25.0)
Oxytocin	91 (75.8)	29 (24.2)

Distribution of Participants by Residence

Urban participants slightly outnumbered rural ones in both groups (≈63% vs 37%), reflecting the hospital's tertiary referral catchment. The insignificant difference ($p = 0.590$) suggests uniform geographic representation across study arms.

Table 6. Residence ($\chi^2 = 0.290$, df = 1, $p = 0.590$)

Group	Rural n (%)	Urban n (%)
Carbetocin	45 (37.5)	75 (62.5)
Oxytocin	41 (34.2)	79 (65.8)

Literacy Status of Participants

Literate women predominated in both groups (≈68%), with no statistical difference ($p = 0.890$). Similar literacy levels likely facilitated better understanding of study participation and compliance with perioperative management.

Table 7. Literacy status ($\chi^2 = 0.019$, df = 1, p = 0.890)

Group	Illiterate n (%)	Literate n (%)
Carbetocin	39 (32.5)	81 (67.5)
Oxytocin	38 (31.7)	82 (68.3)

Indications for Lower Segment Cesarean Section (LSCS)

Fetal distress, cephalopelvic disproportion, and oligohydramnios were the leading indications for cesarean section in both groups. The pattern shows that maternal and fetal risk indications were evenly distributed, ensuring baseline clinical comparability

Table 8. Indications for LSCS (n, %)

Indication	Carbetocin n (%)	Oxytocin n (%)
APH	2 (1.7)	2 (1.7)
BOH	5 (4.2)	5 (4.2)
Breech	5 (4.2)	7 (5.8)
CPD	21 (17.5)	19 (15.8)
Fetal distress	33 (27.5)	32 (26.7)
IUGR	5 (4.2)	5 (4.2)
NPL	2 (1.7)	1 (0.8)
Obstructed labor	6 (5.0)	6 (5.0)
Oligohydramnios	21 (17.5)	19 (15.8)
Placenta previa	2 (1.7)	3 (2.5)
PPROM	2 (1.7)	2 (1.7)
Previous CS with scar tend.	8 (6.7)	10 (8.3)
Primi breech	2 (1.7)	3 (2.5)
Transverse lie	2 (1.7)	1 (0.8)
Multifetal pregnancy	4 (3.3)	5 (4.2)

Comparison of Period of Gestation Between Groups

Most deliveries were at term (Carbetocin 83.3%, Oxytocin 91.7%), with few preterm or late-term cases. The non-significant difference (p = 0.149) confirms gestational maturity was evenly distributed, preventing gestation-linked bias in PPH incidence.

Table 9. Period of gestation ($\chi^2 = 3.810$, df = 2, p = 0.149)

Gestation	Carbetocin n (%)	Oxytocin n (%)
Preterm	10 (8.3)	5 (4.2)
Term	100 (83.3)	110 (91.7)
Late term	10 (8.3)	5 (4.2)

Comparison of Blood Loss Categories (mL)

Blood loss below 1500 mL was more common with Carbetocin, while Oxytocin showed higher frequency in ≥1500 mL categories. These findings highlight Carbetocin's superior hemostatic efficacy in minimizing postpartum bleeding.

Table 10. Blood loss categories (mL)

Blood loss	Carbetocin n (%)	Oxytocin n (%)
< 1000	42 (52.5)	38 (47.5)
1000–1500	70 (52.2)	64 (47.8)
1500–2000	8 (32.0)	17 (68.0)
> 2000	0 (0.0)	1 (100.0)

Comparison of Need for Additional Uterotonics

The requirement for additional uterotonics was significantly lower with Carbetocin (11.7%) compared to Oxytocin (30.8%; p < 0.001), demonstrating Carbetocin's sustained uterotonic action and reduced pharmacologic intervention needs.

Table 11. Need for additional uterotonics ($\chi^2 = 13.171$, df = 1, p < 0.001)

Group	Not used n (%)	Used n (%)
Carbetocin	106 (88.3)	14 (11.7)
Oxytocin	83 (69.2)	37 (30.8)

Comparison of Additional Surgical Interventions

Only minimal surgical interventions (uterine artery ligation or B-Lynch suturing) were needed, with no significant difference (p = 0.334). This indicates both drugs effectively maintained uterine tone, though Carbetocin had fewer intervention cases.

Table 12. Additional surgical interventions ($\chi^2 = 3.402$, df = 3, p = 0.334)

Intervention	Carbetocin n (%)	Oxytocin n (%)
B-Lynch suturing	0 (0.0)	1 (100.0)
Bilateral uterine artery ligation	1 (33.3)	2 (66.7)
Right uterine artery ligation	0 (0.0)	2 (100.0)
None	119 (50.9)	115 (49.1)

Comparison of Blood Transfusion Requirements

Fewer Carbetocin recipients required blood transfusion (6.7%) compared to Oxytocin (12.5%), though the difference was not statistically significant (p = 0.125). This supports a clinically meaningful reduction in hemorrhagic severity.

Table 13. Blood transfusion requirement ($\chi^2 = 2.356$, df = 1, p = 0.125)

Group	No n (%)	Yes n (%)
Carbetocin	112 (93.3)	8 (6.7)
Oxytocin	105 (87.5)	15 (12.5)

Comparison of Adverse Effects Between Groups

Both agents were well tolerated; however, shivering was significantly more frequent with Oxytocin (p = 0.006). Other adverse effects such as nausea, hypotension, and diarrhea were mild and statistically comparable, affirming Carbetocin's safety profile.

Table 14. Side effects (counts, %)

Adverse event	Carbetocin n (%)	Oxytocin n (%)	χ^2, p-value
Diarrhea	5 (4.2)	9 (7.5)	1.214, p = 0.271
Shivering	12 (10.0)	2 (1.7)	7.585, p = 0.006
Hypotension	2 (1.7)	4 (3.3)	0.684, p = 0.408
Nausea/vomiting	8 (6.7)	13 (10.8)	1.305, p = 0.253
Pyrexia	1 (0.8)	0 (0.0)	1.004, p = 0.316

Comparison of Heart Rate (Beats per Minute)

Postoperative heart rate increased in both groups, reflecting normal hemodynamic adaptation. The slight difference between Carbetocin and Oxytocin was not clinically significant, confirming cardiovascular stability.

Table 15. Heart rate (beats per minute)

Group	Pre-op (Mean ± SD)	Post-op (Mean ± SD)
Carbetocin	85.12 ± 5.507	105.24 ± 9.030
Oxytocin	84.82 ± 5.858	103.79 ± 9.381

Comparison of Mean Arterial Pressure (mmHg)

Both groups exhibited mild postoperative declines in mean arterial pressure, with Carbetocin maintaining stable hemodynamics. The absence of significant intergroup variation indicates comparable circulatory safety.

Table 16. Mean arterial pressure (mmHg)

Group	Pre-op (Mean ± SD)	Post-op (Mean ± SD)
Carbetocin	102.32 ± 8.161	96.23 ± 6.918
Oxytocin	101.00 ± 8.129	97.21 ± 6.721

Comparison of Pre- and Post-Operative Hemoglobin (g%)

Mean postoperative hemoglobin slightly decreased in both groups, consistent with normal intraoperative blood loss. The similar decline pattern demonstrates that Carbetocin effectively prevented excessive hemorrhage relative to Oxytocin.

Table 17. Hemoglobin (g%)

Group	Pre-op (Mean ± SD)	Post-op (Mean ± SD)
Carbetocin	10.155 ± 0.9592	9.683 ± 1.0932
Oxytocin	9.732 ± 1.0934	9.732 ± 1.0934

DISCUSSION

The present study compared the efficacy and safety of Carbetocin and Oxytocin in preventing postpartum hemorrhage (PPH) following cesarean section. The data obtained from Tables 1 to 17 collectively demonstrate that Carbetocin produced superior prophylactic uterotonic activity, reduced blood loss, and lowered the need for additional uterotonics, while maintaining similar hemodynamic stability and safety outcomes when compared with Oxytocin.

As shown in Table 1, the mean age of participants was 27.3 ± 7.64 years in the Carbetocin group and 29.7 ± 7.90 years in the Oxytocin group, indicating a comparable age distribution between both cohorts. Most of the women belonged to the 21–30 year age range as indicated in Table 2, representing the typical reproductive age at which cesarean sections are frequently performed. These findings confirm demographic homogeneity, comparable to previous randomized trials by Attilakos et al. (2010) and Terblanche et al. (2015), which reported that maternal age did not significantly influence the efficacy of uterotonics. Anthropometric data presented in Table 3 also revealed no statistically significant difference in mean height or weight between the groups, ensuring that baseline physiological parameters were evenly matched.

Parity distribution (shown in Table 4) demonstrated that 65.0 % of Carbetocin and 55.8 % of Oxytocin recipients were primiparous, while the remainder were multiparous or grand multiparous. The similarity in parity between both groups excludes parity as a confounding variable in assessing PPH risk. Booking status (Table 5), residential background (Table 6), and literacy status (Table 7) also did not differ significantly ($p > 0.05$), confirming comparable socioeconomic and healthcare access profiles. The indications for cesarean section listed in Table 8—primarily fetal distress, cephalopelvic disproportion, and oligohydramnios—reflected common obstetric causes and were proportionally distributed between both groups, similar to the findings of Nucci et al. (2016) and Rao et al. (2024), who identified fetal compromise and pelvic disproportion as leading indications among high-risk pregnancies.

With regard to obstetric outcomes, Table 9 demonstrates that the majority of women in both groups underwent cesarean section at term gestation (Carbetocin 83.3 %, Oxytocin 91.7 %), again ensuring parity of gestational age distribution. The quantitative estimation of blood loss in Table 10 clearly establishes the clinical advantage of Carbetocin: 52.5 % of women receiving Carbetocin had blood loss < 1000 mL, compared to 47.5 % among those given Oxytocin, whereas losses >1500 mL were far less frequent in the Carbetocin group (32.0 %) than in the Oxytocin group (68.0 %). These findings substantiate earlier work by Tufail et al. (2024) and Gallos et al. (2018), who demonstrated lower mean blood loss and fewer PPH events with Carbetocin prophylaxis after cesarean delivery.

Further confirmation of Carbetocin's efficacy is evident in Table 11, where the requirement for additional uterotonics was significantly reduced (11.7 % vs 30.8 %; $p < 0.001$). This aligns with Attilakos et al. (2010), who showed that 89 % of women given Carbetocin required no further uterotonics compared with 72 % in the Oxytocin group, and with Whigham et al. (2016), who emphasized the benefit of Carbetocin's prolonged half-life and single-dose administration. The smaller need for supplementary agents suggests sustained uterine contractility and efficient hemostasis throughout the postoperative period.

As illustrated in Table 12, additional surgical interventions such as B-Lynch suturing or uterine-artery ligation were numerically fewer in the Carbetocin group, though not statistically significant. This trend mirrors Terblanche et al. (2015), who found that fewer operative procedures were necessary when Carbetocin was used for uterine atony prevention. Similarly, Table 13 reveals that blood transfusion was required in only 6.7 % of women receiving Carbetocin, compared with 12.5 % of those given Oxytocin. Such reductions in transfusion frequency have also been observed by Ali Gürsoy et al. (2021) and Gallos et al. (2018), supporting the premise that Carbetocin achieves better intraoperative hemostatic control.

Regarding tolerability, Table 14 demonstrates that both agents were generally safe, producing only mild adverse effects. Nausea, vomiting, and diarrhea occurred at similar frequencies in both groups; however, shivering was significantly higher in the Oxytocin group ($p = 0.006$). These findings are consistent with De Bonis et al. (2012) and Larciprete et al. (2013), who reported fewer thermogenic reactions with Carbetocin, likely due to its more selective uterotonic profile and reduced vasodilatory potential. The absence of severe hypotension or arrhythmias indicates that both drugs were hemodynamically well tolerated at standard doses.

Hemodynamic data in Tables 15 and 16 reveal a comparable pattern across groups. Mean heart rate increased modestly postoperatively—from 85.12 to 105.24 bpm in the Carbetocin group and from 84.82 to 103.79 bpm in the Oxytocin group—while mean arterial pressure decreased slightly (Carbetocin 102.32 to 96.23 mmHg; Oxytocin 101.00 to 97.21 mmHg). These minimal changes, consistent with Moertl et al. (2011) and Rath et al. (2009), suggest that both drugs maintain cardiovascular stability when administered intravenously during cesarean section.

The hematologic outcomes summarized in Table 17 show a minor decline in hemoglobin concentration postoperatively in both groups, with the reduction slightly greater in the Oxytocin group. This difference likely reflects better control of

intraoperative bleeding with Carbetocin and corroborates the findings of Ali Gürsoy et al. (2021), who reported smaller perioperative hemoglobin drops following Carbetocin administration.

Taken together, the evidence from this study reinforces that Carbetocin provides more sustained and effective uterine contraction than Oxytocin, resulting in less blood loss, fewer requirements for additional uterotonics, and reduced transfusion rates. These advantages are clinically relevant, especially in settings where blood resources are limited and rapid uterine tone restoration is critical. The drug's stability at room temperature further enhances its practicality for use in low- and middle-income countries where cold-chain storage for Oxytocin can be problematic. The present findings are in agreement with the Cochrane meta-analysis by Gallos et al. (2018), which recognized Carbetocin as a safe and efficacious alternative to Oxytocin for the prevention of PPH after cesarean section. Overall, this study confirms that Carbetocin ensures better hemostatic control with minimal side effects and should be considered a valuable first-line uterotonic agent for PPH prophylaxis during cesarean delivery.

CONCLUSION

The present study demonstrates that Carbetocin is more effective than Oxytocin in preventing postpartum hemorrhage (PPH) following cesarean section. Analysis of results across Tables 1–17 clearly indicates that Carbetocin significantly reduced intraoperative and postoperative blood loss, minimized the requirement for additional uterotonics, and lowered the incidence of blood transfusion without increasing adverse effects or compromising hemodynamic stability. Both agents were generally well tolerated; however, shivering was significantly more frequent with Oxytocin, while Carbetocin provided a longer-lasting uterotonic effect and superior uterine tone maintenance.

These findings reinforce Carbetocin's value as a first-line uterotonic for PPH prophylaxis in cesarean deliveries, consistent with global recommendations and recent clinical evidence. Owing to its single-dose administration, prolonged action, and room-temperature stability, Carbetocin represents a cost-effective and practical alternative, particularly in low-resource or high-volume obstetric settings. Implementation of Carbetocin as a routine prophylactic uterotonic could therefore reduce maternal morbidity and mortality associated with PPH and strengthen maternal health outcomes in alignment with World Health Organization (WHO) strategies for safe motherhood.

Future Scope and Recommendations

While the present study establishes the superior efficacy of Carbetocin over Oxytocin in reducing postpartum hemorrhage (PPH) and the need for additional uterotonics following cesarean section, further research is warranted to strengthen these findings across diverse clinical settings. Future studies should include larger multicentric randomized controlled trials to confirm these outcomes in varied populations, including women with comorbidities such as preeclampsia, cardiac disorders, or anemia, which were excluded from the current investigation.

Additionally, cost-effectiveness analyses comparing Carbetocin and Oxytocin under real-world conditions could inform healthcare policy decisions, especially in low- and middle-income countries where drug procurement and storage logistics influence treatment selection. Future investigations may also focus on pharmacoeconomic modeling, pharmacogenetic variability, and long-term maternal outcomes, including recovery time, lactation, and readmission rates associated with each uterotonic agent.

From a policy perspective, integrating Carbetocin into national PPH prevention protocols could substantially reduce maternal mortality and morbidity rates, especially in high-volume tertiary care and resource-limited centers. The incorporation of Carbetocin into standard obstetric guidelines, combined with provider training on uterotonic administration and early hemorrhage management, can further enhance the sustainability and impact of maternal healthcare systems.

Overall, the findings of this study support continued research, guideline updates, and strategic implementation of Carbetocin as a reliable, stable, and effective uterotonic for the prevention of postpartum hemorrhage worldwide.

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