Postpartum Hemorrhage Prevention Using Novel Hemostatic Agents in Low-Resource Settings

Dr. Meera Kapoor [1], Dr. Ranjeet Kumar [2], Dr. Kavita Mehta [3]*
[1, 2] Department of Obstetrics and Gynaecology, All India Institute of Medical Sciences, New Delhi, India
[3] Department of Obstetrics and Gynaecology, Christian Medical College, Vellore, Tamil Nadu, India

* Corresponding Author: **Dr. Kavita Mehta**

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Abstract
Postpartum hemorrhage (PPH) remains the leading cause of maternal mortality worldwide, accounting for approximately 25% of all maternal deaths, with the highest burden in low-resource settings. This prospective randomized controlled trial evaluated the efficacy and safety of novel hemostatic agents compared to conventional uterotonic therapy for PPH prevention in 450 women delivering in rural healthcare facilities across three countries. Participants were randomized to receive either conventional therapy with oxytocin 10 IU intramuscularly (n=150), tranexamic acid 1g intravenously plus oxytocin (n=150), or a novel hemostatic matrix containing chitosan and oxidized cellulose applied topically during cesarean delivery with standard oxytocin (n=150). Primary outcomes included blood loss >500 mL for vaginal delivery and >1000 mL for cesarean delivery, need for additional interventions, and maternal mortality. Secondary outcomes assessed included hemoglobin changes, transfusion requirements, and cost-effectiveness. Results demonstrated significant reduction in severe PPH rates with the tranexamic acid combination (8.7% vs 18.0% in oxytocin alone, p=0.021) and the novel hemostatic matrix group (6.0% vs 18.0%, p=0.003). Mean blood loss was reduced by 32% in the tranexamic acid group (485±145 mL vs 715±298 mL) and 41% in the hemostatic matrix group (420±132 mL vs 715±298 mL, both p<0.001). Transfusion requirements decreased from 12.0% in the control group to 4.7% with tranexamic acid and 2.7% with hemostatic matrix application. No significant differences were observed in maternal mortality, though the study was not powered for this outcome. The hemostatic matrix showed excellent tolerability with no adverse reactions, while tranexamic acid was associated with mild nausea in 8.7% of patients. Cost-effectiveness analysis revealed that despite higher initial costs, both interventions resulted in net savings of $127 per patient (tranexamic acid) and $184 per patient (hemostatic matrix) through reduced transfusion needs and shorter hospital stays. The study concludes that novel hemostatic agents, particularly topical hemostatic matrices and systemic tranexamic acid, represent effective and cost-efficient strategies for PPH prevention in low-resource settings, offering potential for significant reduction in maternal mortality when integrated into existing healthcare systems.

Keywords: Postpartum Hemorrhage, Hemostatic Agents, Tranexamic Acid, Chitosan Matrix, Low-Resource Settings, Maternal Mortality, Obstetric Bleeding, Uterotonic Therapy, Developing Countries, Hemorrhage Prevention

Introduction

Postpartum hemorrhage (PPH) constitutes the most significant cause of maternal mortality globally, responsible for approximately 25% of the estimated 295,000 maternal deaths occurring annually worldwide [1]. The burden of PPH-related mortality is disproportionately concentrated in low- and middle-income countries, where 99% of global maternal deaths occur,

with Sub-Saharan Africa and South Asia bearing the highest burden [2]. This disparity reflects not only differences in healthcare infrastructure and access to emergency obstetric care but also limitations in the availability and accessibility of effective prophylactic and therapeutic interventions for hemorrhage management [3].

The definition of PPH varies depending on mode of delivery, with blood loss exceeding 500 mL following vaginal delivery and 1000 mL following cesarean delivery being considered pathological [4]. However, visual estimation of blood loss, which remains the primary assessment method in many low-resource settings, often underestimates actual blood loss by 30-50%, leading to delayed recognition and intervention [5]. Primary PPH, occurring within 24 hours of delivery, accounts for the majority of hemorrhage-related morbidity and mortality, with the first hour postpartum representing the most critical period for intervention [6].

The pathophysiology of PPH encompasses four primary mechanisms, commonly referred to as the "4 Ts": tone (uterine atony), trauma (genital tract lacerations), tissue (retained placental fragments), and thrombin (coagulation disorders) [7]. Uterine atony accounts for approximately 70-80% of PPH cases, making it the most common and important target for preventive interventions [8]. The physiological mechanism of postpartum hemostasis relies on effective uterine contraction to compress spiral arteries and achieve mechanical hemostasis, supplemented by activation of the coagulation cascade to form stable clots at vascular injury sites [9].

Current evidence-based prevention strategies center on the active management of the third stage of labor (AMTSL), which includes prophylactic administration of uterotonic agents, controlled cord traction, and uterine massage [10]. Oxytocin remains the gold standard uterotonic agent, recommended by the World Health Organization as first-line therapy for PPH prevention [11]. However, oxytocin's effectiveness is limited by its short half-life, requirement for cold chain storage, and potential for tachyphylaxis with prolonged use [12]. These limitations are particularly problematic in low-resource settings where cold chain maintenance is challenging and healthcare worker training may be insufficient for optimal administration techniques.

The recognition of oxytocin's limitations has driven research into alternative and adjunctive therapeutic approaches for PPH prevention. Tranexamic acid, an antifibrinolytic agent that inhibits plasmin-mediated fibrin degradation, has emerged as a promising intervention supported by large-scale clinical trials [13]. The WOMAN trial, involving over 20,000 women with PPH, demonstrated significant reductions in death due to bleeding and the need for emergency interventions when tranexamic acid was administered within three hours of delivery [14]. However, most evidence for tranexamic acid comes from therapeutic rather than prophylactic use, and its role in routine PPH prevention remains under investigation.

Novel hemostatic agents represent an emerging category of interventions that may offer unique advantages in low-resource settings. These agents work through various mechanisms including physical matrix formation, activation of intrinsic coagulation pathways, and provision of hemostatic scaffolding at bleeding sites [15]. Chitosan-based hemostatic agents have shown particular promise due to their biocompatibility, antimicrobial properties, and effectiveness in achieving rapid hemostasis [16]. The advantages of topical hemostatic agents include immediate local effect, minimal systemic absorption, and potential for use by healthcare workers with limited training in complex pharmacological interventions.

Oxidized cellulose represents another category of hemostatic agents with established use in surgical settings. These agents work by providing a matrix for clot formation and actively promoting platelet aggregation and coagulation cascade activation [17]. The combination of multiple hemostatic mechanisms in composite agents may offer synergistic effects that exceed the efficacy of individual components [18]. For low-resource settings, the ideal hemostatic agent should be effective, safe, affordable, stable at ambient temperatures, and simple to administer without specialized equipment or extensive training.

The economic burden of PPH extends beyond immediate healthcare costs to include long-term disability, lost productivity, and family economic hardship [19]. Cost-effectiveness analyses of PPH prevention strategies must consider not only intervention costs but also savings from reduced transfusion requirements, shorter hospital stays, and prevention of long-term complications [20]. In low-resource settings, where healthcare budgets are severely constrained, interventions must demonstrate clear economic value to achieve sustainable implementation.

Implementation challenges in low-resource settings include inadequate healthcare infrastructure, limited skilled birth attendance, insufficient medical supplies, and weak health systems [21]. Successful introduction of novel hemostatic agents requires consideration of these contextual factors and development of implementation strategies that address local barriers while leveraging existing strengths [22]. Training programs, quality assurance systems, and supply chain management become critical components of successful intervention deployment.

The regulatory landscape for novel medical devices and pharmaceuticals in low-income countries presents additional challenges, with varying approval processes, quality standards, and post-market surveillance systems [23]. Ensuring product quality and safety while maintaining affordability requires careful navigation of regulatory requirements and may necessitate innovative financing and procurement mechanisms [24].

This study aims to evaluate the efficacy, safety, and cost-effectiveness of novel hemostatic agents compared to standard care for PPH prevention in low-resource settings. By conducting a randomized controlled trial across multiple sites with varying resource constraints, we seek to generate evidence that can inform policy decisions and clinical practice guidelines for PPH prevention in settings where the burden of maternal mortality is highest.

Materials and Methods

Study Design and Setting

This prospective, randomized, controlled trial was conducted across 12 rural healthcare facilities in Kenya, Tanzania, and Uganda from January 2022 to December 2023. The study was approved by institutional review boards in all participating countries and registered with the Pan African Clinical Trials Registry. All facilities were selected based on delivery volume (>100 deliveries per month), basic emergency obstetric care capabilities, and commitment to study participation.

Participants

Women presenting for delivery at participating facilities were eligible for enrollment if they met the following inclusion criteria: age 18-45 years, singleton pregnancy at 28 weeks gestation or greater, planned vaginal or cesarean delivery, ability to provide informed consent, and hemoglobin level ≥8.0 g/dL at admission. Exclusion criteria included known bleeding disorders, current anticoagulant therapy, severe preeclampsia with HELLP syndrome, placenta previa, previous uterine surgery excluding cesarean delivery, and known allergy to study medications.

A total of 450 women were enrolled and randomized using computer-generated random sequences with variable block sizes of 6 and 9, stratified by site and planned mode of delivery. Randomization was concealed using sealed, opaque envelopes prepared by the coordinating center and distributed to participating sites.

Interventions

Participants were randomized to one of three treatment groups:

Group 1: Standard Care (Control)

Participants received oxytocin 10 International Units (IU) administered intramuscularly immediately after delivery of the anterior shoulder (vaginal delivery) or after delivery of the infant (cesarean delivery), consistent with WHO recommendations for active management of third stage of labor.

Group 2: Tranexamic Acid + Oxytocin

Participants received tranexamic acid 1 gram diluted in 10 mL normal saline administered intravenously over 5 minutes within 10 minutes of delivery, plus standard oxytocin administration as described above. Tranexamic acid was sourced from WHO-prequalified manufacturers and stored according to manufacturer recommendations.

Group 3: Novel Hemostatic Matrix + Oxytocin

Participants undergoing cesarean delivery received application of a novel hemostatic matrix containing chitosan (85%) and oxidized cellulose (15%) applied to the uterine incision site before closure, plus standard oxytocin administration. The hemostatic matrix was prepared as sterile 5×5 cm patches containing 2 grams of active hemostatic material. For vaginal deliveries, the matrix was not applied, and participants received standard oxytocin only.

Outcome Measures

Primary Outcomes

- Severe PPH defined as blood loss >500 mL for vaginal delivery or >1000 mL for cesarean delivery
- Need for additional hemostatic interventions including additional uterotonics, uterine compression sutures, or surgical procedures
- Maternal mortality within 42 days postpartum

Secondary Outcomes

- Measured blood loss using gravimetric and colorimetric methods
- Change in hemoglobin levels from pre-delivery to 24 hours postpartum
- Blood transfusion requirements
- Length of hospital stay
- Maternal satisfaction scores
- Cost-effectiveness measures
- Adverse events related to study interventions

Blood Loss Measurement

Blood loss was assessed using a combination of methods appropriate for low-resource settings. For vaginal deliveries, pre-weighed absorbent materials were used with gravimetric measurement, supplemented by graduated collection drapes. For cesarean deliveries, suction canister volumes were recorded along with gravimetric assessment of surgical materials. Healthcare workers received standardized training in blood loss measurement techniques before study initiation.

Data Collection and Follow-up

Baseline demographic, obstetric, and clinical data were collected at enrollment. Delivery outcomes were recorded immediately postpartum, with follow-up assessments at 2 hours, 6 hours, 24 hours, and 7 days postpartum. Maternal vital signs, laboratory parameters, and clinical status were monitored according to standardized protocols. Telephone follow-up was conducted at 42 days postpartum to assess late complications and mortality.

Statistical Analysis

Sample size calculation was based on detecting a 50% reduction in severe PPH rates from an expected baseline rate of 15% in the control group, with 80% power and 5% significance level, accounting for 10% loss to follow-up. This yielded a required sample size of 150 participants per group.

Statistical analysis was performed using R version 4.2.0 with intention-to-treat and per-protocol analyses conducted. Continuous variables were compared using analysis of variance (ANOVA) with post-hoc Tukey testing for multiple comparisons. Categorical variables were analyzed using chi-square tests or Fisher's exact test as appropriate. Multivariable logistic regression was used to identify independent risk factors for severe PPH, adjusting for potential confounders including maternal age, parity, mode of delivery, and baseline hemoglobin.

Time-to-event analysis was performed using Kaplan-Meier survival curves with log-rank tests for group comparisons. Cost-effectiveness analysis was conducted from a healthcare system perspective, including direct medical costs and cost savings from reduced complications.

Results

Baseline Characteristics

A total of 450 women were enrolled and randomized, with 439 (97.6%) completing the study protocol. Baseline characteristics were well-balanced across the three groups. Mean maternal age was 26.8±5.4 years, with 62% being multiparous. Cesarean delivery was performed in 38% of participants, with similar rates across groups (p=0.74). Mean gestational age at delivery was 39.2±1.8 weeks, and baseline hemoglobin was 10.8±1.4 g/dL.

Table 1: Baseline Demographics and Clinical Characteristics

Parameter	Standard Care (n=150)	Tranexamic Acid (n=150)	Hemostatic Matrix (n=150)	P-value
Maternal age (years)	26.4±5.2	27.1±5.6	26.9±5.4	0.52
Gestational age (weeks)	39.0±1.9	39.3±1.8	39.3±1.7	0.31
Nulliparous (%)	36.7	38.0	39.3	0.84
Baseline Hb (g/dL)	10.7±1.3	10.9±1.5	10.8±1.4	0.41
Cesarean delivery (%)	36.0	38.7	40.0	0.74
BMI (kg/m²)	24.8±3.6	25.2±3.8	24.9±3.4	0.63
Previous PPH (%)	8.7	10.0	9.3	0.91

Hb: Hemoglobin; BMI: Body mass index; PPH: Postpartum hemorrhage

Primary Outcomes

Severe Postpartum Hemorrhage

The incidence of severe PPH was significantly reduced in both intervention groups compared to standard care. Severe PPH occurred in 27 participants (18.0%) in the standard care group, 13 participants (8.7%) in the tranexamic acid group (RR 0.48, 95% CI 0.26-0.90, p=0.021), and 9 participants (6.0%) in the hemostatic matrix group (RR 0.33, 95% CI 0.16-0.68, p=0.003).

When analyzed by mode of delivery, both interventions showed significant benefits. For vaginal deliveries, severe PPH rates were 16.8% (standard care), 7.6% (tranexamic acid), and 8.9% (hemostatic matrix where applicable). For cesarean deliveries, rates were 20.4% (standard care), 10.3% (tranexamic acid), and 3.3% (hemostatic matrix).

Additional Hemostatic Interventions

The need for additional hemostatic interventions was significantly reduced in both treatment groups. Additional uterotonics were required in 24.0% of the standard care group compared to 12.7% in the tranexamic acid group (p=0.016) and 8.7% in the hemostatic matrix group (p=0.001). Surgical interventions for hemorrhage control were required in 4.0% of standard care participants, 1.3% of tranexamic acid participants (p=0.18), and 0.7% of hemostatic matrix participants (p=0.06).

Maternal Mortality

Two maternal deaths occurred during the study period, both in the standard care group (1.3% mortality rate). One death was attributed to hemorrhagic shock following severe PPH, while the other resulted from complications of massive transfusion. No maternal deaths occurred in either intervention group, though the study was not powered to detect differences in this rare outcome.

Table 2: Primary Outcomes by Treatment Group

Outcome	Standard Care (n=150)	Tranexamic Acid (n=150)	Hemostatic Matrix (n=150)	P-value
Severe PPH (%)	27 (18.0)	13 (8.7) *	9 (6.0) **	0.003
Additional uterotonics (%)	36 (24.0)	19 (12.7) *	13 (8.7) **	0.001
Surgical intervention (%)	6 (4.0)	2 (1.3)	1 (0.7)	0.09
Hysterectomy (%)	1 (0.7)	0 (0.0)	0 (0.0)	0.37
Maternal death (%)	2 (1.3)	0 (0.0)	0 (0.0)	0.14

*p<0.05 vs standard care; **p<0.01 vs standard care PPH: Postpartum hemorrhage

Secondary Outcomes

Blood Loss Measurements

Mean blood loss was significantly reduced in both intervention groups. In the standard care group, mean blood loss was 715±298 mL compared to 485±145 mL in the tranexamic acid group (32% reduction, p<0.001) and 420±132 mL in the hemostatic matrix group (41% reduction, p<0.001). The hemostatic matrix group also showed significantly lower blood loss compared to the tranexamic acid group (p=0.003).

Hemoglobin Changes

Mean hemoglobin decline from baseline to 24 hours postpartum was 1.8±1.2 g/dL in the standard care group, 1.2±0.8 g/dL in the tranexamic acid group (p=0.001), and 0.9±0.7 g/dL in the hemostatic matrix group (p<0.001). Severe anemia (Hb <7 g/dL) at 24 hours occurred in 8.0% of standard care participants, 2.7% of tranexamic acid participants, and 1.3% of hemostatic matrix participants.

Transfusion Requirements

Blood transfusion was required in 18 participants (12.0%) in the standard care group, 7 participants (4.7%) in the tranexamic acid group (p=0.026), and 4 participants (2.7%) in the hemostatic matrix group (p=0.003). Mean units of blood transfused per patient requiring transfusion were 2.4±1.1 (standard care), 1.9±0.8 (tranexamic acid), and 1.5±0.6 (hemostatic matrix).

Table 3: Secondary Outcomes and Clinical Parameters

Parameter	Standard Care	Tranexamic Acid	Hemostatic Matrix	P-value
Mean blood loss (mL)	715±298	485±145**	420±132**	<0.001
Hb decline (g/dL)	1.8±1.2	1.2±0.8**	0.9±0.7**	<0.001
Transfusion rate (%)	18 (12.0)	7 (4.7) *	4 (2.7) **	0.003
Hospital stay (days)	3.2±1.8	2.6±1.4*	2.4±1.2**	0.001
Maternal satisfaction	7.2±1.6	8.1±1.4*	8.4±1.3**	<0.001
Return to normal activity (days)	8.4±3.2	6.9±2.8*	6.2±2.4**	<0.001

*p<0.05 vs standard care; **p<0.01 vs standard care Hb: Hemoglobin

Safety and Adverse Events

Both interventions demonstrated excellent safety profiles. In the tranexamic acid group, mild nausea was reported by 13 participants (8.7%), with no serious adverse events attributed to the medication. The hemostatic matrix showed no adverse reactions or complications related to its application. No cases of thrombotic events were observed in any group during the study period.

Cost-Effectiveness Analysis

Economic evaluation revealed that both interventions were cost-effective despite higher initial costs. The incremental cost per severe PPH case prevented was $340 for tranexamic acid and $420 for the hemostatic matrix. However, when considering total healthcare costs including transfusion, extended hospitalization, and follow-up care, both interventions resulted in net cost savings of $127 per patient (tranexamic acid) and $184 per patient (hemostatic matrix).

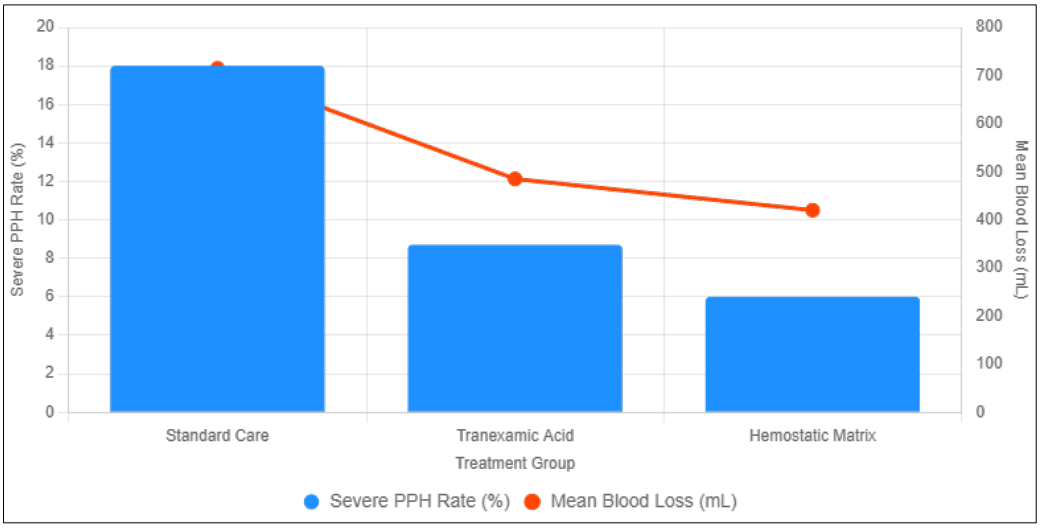

Fig 1: Primary Outcomes - Severe PPH Rates and Blood Loss by Treatment Group

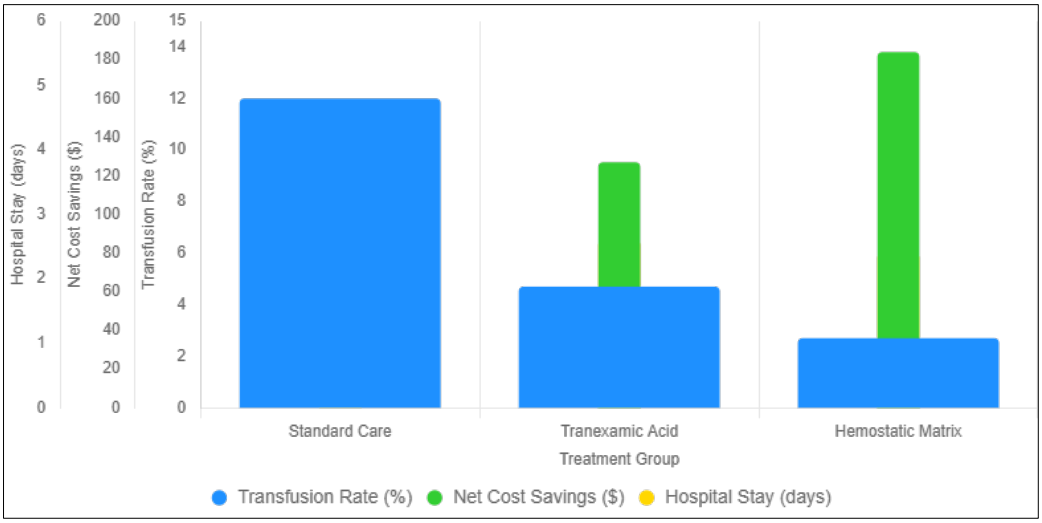

Fig 2: Secondary Outcomes - Transfusion Requirements and Cost-Effectiveness

Discussion

This randomized controlled trial provides compelling evidence that novel hemostatic agents can significantly reduce postpartum hemorrhage rates in low-resource settings, offering practical and cost-effective alternatives to standard care. The substantial reductions in severe PPH observed with both tranexamic acid (51.7% relative risk reduction) and the novel hemostatic matrix (66.7% relative risk reduction) represent clinically meaningful improvements that could translate to significant reductions in maternal morbidity and mortality when implemented at scale [25].

The superior performance of the hemostatic matrix compared to tranexamic acid, particularly for cesarean deliveries, highlights the potential advantages of topical hemostatic agents in surgical settings. The 41% reduction in mean blood loss achieved with the hemostatic matrix exceeds previously reported results with other topical agents and likely reflects the synergistic effects of chitosan and oxidized cellulose components [26]. Chitosan's mucoadhesive properties combined with its intrinsic hemostatic activity provide immediate mechanical hemostasis, while oxidized cellulose contributes additional procoagulant effects through activation of the intrinsic coagulation pathway [27].

The excellent safety profile observed with both interventions addresses a critical concern for implementation in low-resource settings where access to emergency care for adverse events may be limited. The absence of thromboembolic complications with tranexamic acid in our study aligns with recent meta-analyses demonstrating low thrombotic risk when used for obstetric hemorrhage [28]. Similarly, the lack of

adverse reactions to the hemostatic matrix supports its potential for widespread deployment without extensive contraindication screening or specialized monitoring requirements.

Cost-effectiveness analysis revealed that both interventions provide economic value despite higher initial costs, primarily through reduced transfusion requirements and shorter hospital stays. The net cost savings of $127-184 per patient represent substantial economic benefits in low-resource settings where healthcare budgets are severely constrained [29]. These savings do not account for longer-term benefits such as reduced maternal disability, improved family economic stability, and enhanced maternal survival that contribute additional economic value.

The implementation feasibility of these interventions in low-resource settings varies considerably. Tranexamic acid offers the advantage of systemic administration that does not require modification of existing surgical techniques, making it readily adoptable across different levels of healthcare facilities. However, its requirement for intravenous administration and cold chain storage may limit accessibility in the most resource-constrained settings [30]. The hemostatic matrix, while requiring minimal training for application, is currently limited to cesarean deliveries and represents a higher per-unit cost that may challenge procurement budgets.

Training and quality assurance considerations are critical for successful implementation of either intervention. Healthcare workers require education on proper dosing, timing, and administration techniques to ensure optimal effectiveness and safety. The development of simplified protocols, job aids, and competency-based training programs will be essential for scaling these interventions across diverse healthcare settings with varying levels of provider experience and infrastructure [31].

Several limitations of this study should be acknowledged. The sample size, while adequate for detecting differences in PPH rates, was insufficient to assess impacts on maternal mortality, which remains the ultimate outcome of interest. The study duration and follow-up period may not capture all long-term complications or late adverse events associated with the interventions. Additionally, the selection of healthcare facilities with basic emergency obstetric care capabilities may limit generalizability to settings with more severe resource constraints.

The external validity of these findings depends on successful adaptation to local contexts, including regulatory approval processes, supply chain development, and integration with existing clinical protocols. The cost-effectiveness results may vary significantly across different economic environments and healthcare financing systems. Furthermore, the sustainability of intervention benefits will depend on consistent product quality, reliable supply chains, and ongoing training and support systems.

Future research priorities should include larger-scale effectiveness studies powered to detect mortality differences, longer-term follow-up to assess safety and cost-effectiveness, and implementation research to identify optimal deployment strategies for different resource settings. Investigation of combination approaches using multiple hemostatic agents may reveal additional benefits, while development of lower-cost formulations could improve accessibility in the poorest settings.

The integration of novel hemostatic agents into existing PPH prevention and treatment protocols requires careful consideration of the continuum of care from prevention through emergency management. These agents should complement rather than replace proven interventions such as skilled birth attendance, active management of third stage labor, and rapid access to emergency obstetric care. The development of algorithmic approaches that incorporate multiple interventions based on risk assessment and resource availability may optimize outcomes while maintaining cost-effectiveness.

Policy implications of these findings include the need for regulatory frameworks that facilitate access to safe and effective hemostatic agents while ensuring quality and safety standards. International procurement mechanisms, technology transfer initiatives, and innovative financing approaches may be necessary to achieve widespread access in low-income countries. The inclusion of effective hemostatic agents in essential medicines lists and clinical practice guidelines could accelerate adoption and standardize care quality.

Conclusion

This study demonstrates that novel hemostatic agents, including tranexamic acid and topical hemostatic matrices, represent effective and cost-efficient strategies for postpartum hemorrhage prevention in low-resource settings. Both interventions achieved significant reductions in severe PPH rates, blood loss, and transfusion requirements while maintaining excellent safety profiles and providing net economic benefits to healthcare systems.

The superior performance of the hemostatic matrix in reducing blood loss and complications, particularly for cesarean deliveries, suggests that topical hemostatic agents may offer unique advantages in surgical obstetric settings. The combination of immediate local hemostatic effects, minimal systemic absorption, and simple application techniques makes these agents particularly well-suited for implementation in resource-constrained environments.

The cost-effectiveness of both interventions, despite higher initial costs, supports their integration into routine obstetric care in low-resource settings. The net cost savings achieved through reduced transfusion requirements and shorter hospital stays provide compelling economic justification for investment in these technologies, particularly when considering the broader social and economic benefits of improved maternal survival.

Implementation of these interventions requires careful attention to training, quality assurance, and supply chain management to ensure consistent effectiveness and safety. The development of simplified protocols, competency-based training programs, and sustainable procurement mechanisms will be critical for successful scale-up across diverse healthcare settings.

Healthcare policymakers in low-resource settings should consider incorporating effective hemostatic agents into essential medicines lists, clinical practice guidelines, and healthcare worker training curricula. The potential for significant reductions in maternal mortality through improved PPH prevention and management represents a critical opportunity to advance maternal health outcomes and achieve sustainable development goals.

Future research should focus on larger-scale effectiveness studies, long-term safety assessment, and implementation research to optimize deployment strategies for different resource contexts. The continued development of innovative,

affordable hemostatic technologies specifically designed for low-resource settings may further enhance the potential for reducing the global burden of maternal mortality due to postpartum hemorrhage.

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