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# Non-Surgical Management of Postpartum Hemorrhage: A Comprehensive Review of Evidence-Based Interventions

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**ABSTRACT**
Postpartum hemorrhage (PPH) remains the leading cause of maternal mortality worldwide, accounting for approximately 140,000 deaths annually and representing nearly one-quarter of all maternal deaths. The evolution from surgical-dominant approaches toward stepwise conservative management constitutes a paradigm shift in obstetric care with profound implications for maternal survival and fertility preservation. This review provides a comprehensive evaluation of evidence-based non-surgical interventions for PPH management, with emphasis on efficacy in reducing maternal mortality while preserving reproductive potential across diverse healthcare settings. systematic literature synthesis was performed using MEDLINE, EMBASE, and the Cochrane Library databases. Studies were included if they reported outcomes of non-surgical interventions for PPH published between 2000 and 2025, supplemented by landmark earlier trials. Evidence was graded using established hierarchies, prioritizing randomized controlled trials, systematic reviews, and meta-analyses. The landmark WOMAN trial demonstrated that tranexamic acid (TXA) reduces death due to bleeding by 19-31% when administered within three hours of birth. Uterine balloon tamponade (UBT) achieves hemostasis in 80-98% of cases when appropriately applied, with improvised condom-catheter devices achieving comparable efficacy (88-96%) at a fraction of the cost (USD 0.64-6 vs. USD 300-400 for commercial devices). Uterine artery embolization (UAE) demonstrates success rates exceeding 90-98% for refractory hemorrhage while preserving fertility in 50–71% of women attempting subsequent conception. The E-MOTIVE protocol, incorporating early detection and bundled first-line interventions, reduces severe PPH and maternal death by 60% compared to standard care.Universal implementation of evidence-based non-surgical interventions—organized within standardized care bundles—can transform PPH from a leading cause of maternal death to a manageable complication. Addressing the persistent disparity in PPH outcomes between high-resource and low-resource settings requires context-appropriate strategies, sustained training, and health systems investment.

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**Key Words**
Postpartum hemorrhage, non-surgical management, Uterine balloon tamponade, Uterine artery embolization, Tranexamic acid, E-MOTIVE protocol, Maternal mortality; Uterine preservation

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## INTRODUCTION

**Global Burden of Postpartum Hemorrhage:** Postpartum hemorrhage (PPH) persists as the leading cause of maternal morbidity and mortality worldwide, constituting a tenacious global health challenge despite decades of clinical advancement[1,2,3]. Each year, an estimated 14 million women experience PPH, resulting in approximately 140,000 maternal deaths—equivalent to one woman dying every four minutes from preventable bleeding complications[4,5]. This burden accounts for nearly one-quarter of all maternal deaths annually, with the vast majority occurring in low- and middle-income countries (LMICs) where access to timely obstetric interventions remains critically limited[6,7].

The geographic disparity in PPH-related mortality is stark: 99% of deaths occur in resource-limited settings, where the risk of dying from PPH can be up to 100 times higher than in high-income nations[8,9]. In sub-Saharan Africa and South Asia particularly, inadequate healthcare infrastructure, delayed recognition of hemorrhage, and limited availability of blood products contribute to disproportionately poor outcomes[10,11]. Paradoxically, several high-resource countries—including the United States, Canada, and Australia—have reported increasing PPH incidence rates over the past two decades, potentially attributable to rising rates of labor induction, obesity, and advanced maternal age[12,13].

The clinical impact of PPH extends beyond mortality. Survivors of severe hemorrhage frequently experience hypovolemic shock, disseminated intravascular coagulation (DIC), acute kidney injury, and Sheehan's syndrome[14,15]. From a health systems perspective, PPH imposes substantial economic burdens through prolonged hospitalizations, intensive care utilization, and emergent surgical interventions[16,17].

**Evolution from Surgical to Conservative Management:** Historically, the management of intractable PPH relied heavily on radical surgical interventions, with peripartum hysterectomy serving as the definitive life-saving measure[18,19]. Contemporary obstetric practice has witnessed a paradigm shift toward a stepwise, conservative approach that prioritizes uterine preservation while maintaining maternal safety[20,21]. This evolution reflects growing recognition that many cases of refractory PPH can be successfully managed through non-surgical interventions-advanced pharmacological agents, mechanical compression devices, and minimally invasive interventional radiology procedures[22,23].

The concept of 'conservative management' in PPH encompasses a hierarchical approach beginning with pharmacological therapy, progressing to mechanical interventions such as uterine balloon tamponade (UBT), and culminating in uterine artery embolization (UAE) for cases unresponsive to initial measures[24,25].

Network meta-analyses have demonstrated that non-surgical approaches—particularly UBT and UAE—are associated with significantly lower failure rates leading to hysterectomy compared to traditional surgical procedures alone[26].

**Changing Definitions and Clinical Significance:** The definition of PPH has undergone significant evolution. Traditionally defined as blood loss exceeding 500 mL following vaginal delivery or 1,000 mL after cesarean section, modern definitions proposed by ACOG in 2017 characterize PPH as cumulative blood loss ≥1,000 mL or blood loss accompanied by signs or symptoms of hypovolemia within 24 hours of birth, regardless of delivery route[27]. Visual estimation of blood loss—the historical standard—underestimates actual loss by 35–50%, leading to delayed recognition and intervention[28,29]. Quantified blood loss (QBL) measurement, incorporating calibrated drapes and gravimetric methods, has emerged as the preferred approach.

**Aims:** This review provides a comprehensive evaluation of evidence-based non-surgical interventions for PPH management, encompassing the full spectrum from first-line pharmacological agents through mechanical compression devices to advanced interventional radiology. Special attention is given to context-appropriate solutions for low-resource settings, the integration of interventions within standardized care bundles, and emerging technologies that may further improve maternal outcomes.

## PATHOPHYSIOLOGY AND CLASSIFICATION

**The '4 Ts' Etiological Framework:** PPH is systematically categorized according to the '4 Ts' framework—Tone, Trauma, Tissue, and Thrombin—which provides clinicians with a structured approach to rapidly identify and address the underlying hemorrhage etiology[30,31]. Uterine atony (Tone) accounts for 70–80% of all PPH cases. When myometrial muscle fibers fail to contract adequately following placental delivery, mechanical compression of the spiral arteries is impaired, resulting in rapid and profuse bleeding. Risk factors include prolonged labor, uterine overdistension (multiple gestation, polyhydramnios, macrosomia), chorioamnionitis, and uterine relaxants[32,33].

Trauma-lacerations of the cervix, vagina, or perineum, uterine rupture, or inversion-accounts for approximately 20% of cases. Tissue refers to retained products of conception and abnormal placentation, including placenta accreta spectrum (PAS) disorders, which represent an increasingly significant clinical challenge as cesarean section rates rise globally[34,35]. Thrombin (coagulopathy), while representing less than

Table 1: The '4 Ts' Etiological Classification of Postpartum Hemorrhage

| Etiology | Frequency | Key Causes | Primary Interventions |
|---|---|---|---|
| Tone (Uterine Atony) | 70–80% | Prolonged labor, overdistension, chorioamnionititocolytics | Uterotonics (oxytocin, ergometrine, prostaglandins), UBT, TXA |
| Trauma | ~20% | Genital tract lacerations, uterine rupture, inversion | Surgical repair, UBT as temporizing measure |
| Tissue | ~10% | Retained placenta, placenta accreta spectrum | Uterine evacuation, UAE, multidisciplinary PAS management |
| Thrombin (Coagulopathy) | <1% primary; common secondary | Von Willebrand disease, DIC, dilutional coagulopathy | Fibrinogenreplacement, FFP platelets, rFVIIa (rescue) |

UBT: Uterine balloon tamponade, TXA: Tranexamic acid, UAE: Uterine artery embolization, DIC: Disseminated intravascular coagulation, FFP: Fresh frozen plasma, rFVIIa: Recombinant activated Factor VII, PAS: Placenta accreta spectrum

1% of primary PPH cases as an isolated etiology, is a critical consideration requiring specific hemostatic interventions distinct from standard uterotonic and mechanical approaches[36,37].

**Hemostatic Changes in Pregnancy and Fibrinolysis:** Pregnancy induces a physiological hypercoagulable state through substantially increased concentrations of fibrinogen (4-6 g/L at term vs. 2-4 g/L in non-pregnant women), Factor VIII, and von Willebrand factor[38,39]. During PPH, fibrinogen is the first coagulation factor to decline to critically low levels; a fibrinogen concentration below 2 g/L is a highly predictive marker for progression to severe hemorrhage[38,39]. Standard coagulation tests (PT, aPTT) may remain within normal ranges despite significant depletion, underscoring the value of viscoelastic point-of-care testing.

Hyperfibrinolysis-excessive breakdown of fibrin clots-plays a critical pathophysiological role in severe PPH, creating a vicious cycle of inadequate clot formation and continued consumption of hemostatic resources.

Tranexamic acid (TXA), a synthetic lysine analogue, directly addresses this mechanism by competitively inhibiting plasminogen activation, stabilizing existing fibrin clots and preserving the patient's intrinsic hemostatic response (Table 1)[40].

## PREVENTION STRATEGIES

**Active Management of the Third Stage of Labour:** Active management of the third stage of labour (AMTSL) is internationally recognized as the cornerstone preventive strategy, reducing PPH incidence by approximately 50% compared to expectant management[35,56]. The WHO-defined components include: (1) administration of a uterotonic agent within one minute of birth; (2) controlled cord traction (CCT) to facilitate placental delivery; and (3) uterine massage following placental expulsion[12,19]. Recent evidence emphasizes that uterotonic administration is the most critical element, while CCT may be omitted in settings where skilled providers are unavailable without significantly increasing PPH risk[35].

**Uterotonic Agents for Prophylaxis:** Oxytocin (10 IU intramuscularly or 5 IU intravenously) remains the first-line prophylactic agent, with onset within 2-3 minutes and a well-established safety profile[10,12]. Its primary limitation in low-resource settings is the requirement for cold-chain storage. Heat-stable carbetocin—a long-acting oxytocin analogue retaining potency for at least 36 months at 30°C and 75% relative humidity—has demonstrated non-inferiority to oxytocin in large randomized trials, offering substantial logistical advantages in resource-limited environments[41,42]. Misoprostol (400-600 µg orally), a thermostable prostaglandin E analogue, provides an additional option where injectable uterotonics are unavailable, though with higher rates of side effects including shivering and pyrexia[43,44].

**Risk Stratification and Antenatal Optimization:** Traditional risk factors for PPH include placenta previa, placental abruption, multiple gestation, polyhydramnios, macrosomia, and prior PPH history [3,26]. However, 40-50% of severe PPH cases occur in women with no identifiable antecedent risk factors, underscoring the principle that 'all births are at risk' and vigilance must be universal[19,35]. Structured tools-including the California Maternal Quality Care Collaborative (CMQCC) toolkit and the Safe Motherhood Initiative (SMI) checklist-facilitate risk stratification to guide preparation without inappropriately diverting attention from low-risk patients[3,45].

Antenatal anemia correction is a critical and modifiable intervention, as women with pre-existing anemia tolerate hemorrhage less well. Routine screening, iron supplementation, and intravenous iron for refractory deficiency should be prioritized to maximize pre-delivery hemoglobin reserves [46,47]. For high-risk patients (e.g., those with known PAS or prior massive hemorrhage), multidisciplinary antenatal planning—including notification of blood bank, interventional radiology, and anesthesia—substantially improves preparedness.

## FIRST-LINE NON-SURGICAL INTERVENTIONS

**Pharmacological Management: Uterotonic Algorithm:** Pharmacological intervention constitutes the critical first step in established PPH management, with uterotonic agents forming the therapeutic foundation[48,49]. Oxytocin (5–10 IU IV slowly or 20–40 IU infusion in 1,000 mL crystalloid) acts within 2–3 minutes through myometrial oxytocin receptor stimulation. When oxytocin fails within approximately 15 minutes, second-line uterotonics are indicated. Ergometrine (0.2 mg IM) provides potent sustained contraction but is contraindicated in hypertension and preeclampsia[50]. Carboprost (250 µg IM, repeatable at 15–90-minute intervals up to 8 doses) requires caution in asthma. Misoprostol (800–1,000 µg sublingually or rectally) is particularly valuable in settings lacking injectable alternatives[12,23].

**Tranexamic Acid: Evidence and Clinical Protocols:** Tranexamic acid (TXA) has evolved from a second-line rescue agent to a cornerstone of initial PPH response, supported by robust evidence from the landmark WOMAN trial—a randomized, placebo-controlled study enrolling over 20,000 women[9]. The trial established that 1 gram IV TXA reduces death due to bleeding by 19–31% without increasing thromboembolic risk when administered within three hours of birth. The time-dependency of benefit is critical: every 15-minute delay in administration reduces efficacy, and no mortality benefit is observed beyond three hours.

The standard protocol is 1 gram IV at approximately 100 mg/minute, with a second 1-gram dose if bleeding persists after 30 minutes or restarts within 24 hours[9,51]. Current WHO and ACOG guidelines recommend TXA be administered concurrently with uterotonics at first recognition of significant hemorrhage—addressing both the myometrial and fibrinolytic components simultaneously—rather than reserving it for refractory cases[52].

**Clinical Pearl:** TXA must be immediately available in ALL birth settings. Delayed administration beyond 3 hours eliminates the mortality benefit. Integration into first-line bundle activation—rather than sequential escalation—is essential for maximum efficacy.

**Mechanical Methods: Uterine Massage and Bimanual Compression:** Uterine massage, a fundamental first-step intervention, involves rhythmic massage of the uterine fundus through the abdominal wall, stimulating endogenous prostaglandin release and encouraging myometrial contraction[12,45].

Bimanual uterine compression—with one hand vaginally positioned against the anterior fornix and the other abdominally behind the fundus—provides direct pressure to the bleeding placental bed and serves as a vital temporizing measure when pharmacological therapy is insufficient[19,26]. While physically demanding and not indefinitely sustainable, bimanual compression provides critical time for resuscitation and assembly of personnel for escalation.

**External Aortic Compression and the Non-Pneumatic Anti-Shock Garment:** External aortic compression (EAC), applied via firm pressure at the umbilical level, achieves temporary uterine devascularization by occluding aortic flow[6,24]. Its principal application is in prehospital settings or during transport when immediate surgical intervention is unavailable.

The non-pneumatic anti-shock garment (NASG) applies circumferential counter-pressure (20–40 mmHg) from ankles to diaphragm, redistributing blood volume toward the heart, lungs, and brain and effectively reversing hypovolemic shock physiology[43,52]. Clinical trials in sub-Saharan Africa and South Asia have demonstrated 38–54% reductions in PPH-related maternal mortality with NASG use during stabilization and transport[53]. The garment permits complete perineal access during application, can be safely worn for 48–72 hours, and has been combined with UBT (the 'uterine sandwich' technique) for management of massive hemorrhage with DIC[43].

## SECOND-LINE NON-SURGICAL INTERVENTIONS

**Intrauterine Balloon Tamponade: Devices and Techniques:** Intrauterine balloon tamponade (UBT) represents the primary second-line non-surgical option when first-line interventions fail, functioning through direct hydrostatic pressure against the bleeding uterine surface to tamponade spiral arteries and provide a scaffold for clot formation[21,41]. Reported success rates range from 80–98% across diverse clinical settings[13,21].

Purpose-designed devices include the Bakri balloon (250–500 mL inflation capacity with continuous drainage channel), the Ebb dual-balloon system (incorporating vaginal balloon to prevent expulsion), and the Ellavi and BT-Cath systems[21,28,41]. Prior to insertion, systematic examination must exclude uterine rupture and unaddressed lacerations or retained tissue. The 'tamponade test'—cessation of bleeding through the drainage channel—confirms appropriate patient selection; ongoing brisk bleeding suggests an alternative etiology[19].

**Low-Resource Alternatives: Condom-Catheter Tamponade:** In resource-limited settings, the condom-catheter technique—securing a male condom over a Foley catheter and inflating with 250–500 mL sterile saline—achieves success rates of 88–96%, comparable to commercial devices[27,29]. Material costs of USD 0.64–6 versus USD 300–400 for commercial alternatives represent one of the most dramatic cost-effectiveness differentials in obstetric care. Economic modeling estimates cost of approximately USD 1.00 per disability-adjusted life-year (DALY) averted[22,27].

Evidence for Condom Tamponade: Success rates 88–96% | Cost USD 0.64–6 | Cost per DALY averted ~USD 1.00 | Training packages available for midwives and birth attendants | Strongly recommended for all resource-limited facilities.

Table 2: Comparison of Second-Line Non-Surgical Interventions for Refractory PPH

| Intervention | Success Rate | Key Advantages | Limitations | Fertility Impact |
|---|---|---|---|---|
| Commercial UBT (Bakri) | 80-98% | Rapid deployment; monitors ongoing loss; no radiology needed | CostUSD300–400; riskof expulsion; requires | Minimal; normal fertility intact uterus preserved |
| Condom-Catheter UBT | 88–96% | Cost USD <6; equivalent efficacy; deployable by midwives in LRS | Improvised assembly; variable training | Minimal; normal fertility preserved |
| Uterine Artery Embolization | 90–98% | High success; fertility preservation; controls non-atonic sources | Requires IR suite; not available in LRS; delay to procedure | Live birth rate 50–71%; increased risk preterm/FGR |
| NASG | 38–54% mortality reduction | Reverses shock; non-; 48–72h safe wear | Temporizing only; does not control bleeding source | No impact on fertility |

UBT: Uterine balloon tamponade, LRS: Low-resource settings, IR: Interventional radiology, NASG: Non-pneumatic anti-shock garment, FGR: Fetal growth restriction

**Uterine Artery Embolization: Indications, Technique, and Outcomes:**Uterine artery embolization (UAE) offers a minimally invasive alternative to surgical procedures for refractory PPH, involving selective catheterization and embolization of the uterine arteries under fluoroscopic guidance[5,40]. Indications span both elective (prophylactic intra-arterial balloon placement for anticipated massive hemorrhage in PAS) and emergency (persistent PPH refractory to medical therapy and UBT) scenarios[2,46].

Systematic reviews and case series report hemorrhage control success rates exceeding 90–98%, with the majority of patients avoiding laparotomy and hysterectomy[5,40,46]. Long-term fertility outcomes are favorable: return of regular menses occurs in nearly 100% of patients, and successful live births have been documented in 50–71% of women attempting subsequent conception following UAE for PPH[32,40]. However, post-UAE pregnancies may carry increased risks of preterm delivery (12–25%), fetal growth restriction (10–15%), and placental abnormalities, necessitating enhanced antenatal surveillance (Table 2)[46].

## HEMOSTATIC AND SUPPORTIVE PHARMACOTHERAPY

**Fibrinogen Replacement:** Fibrinogen is the first coagulation factor to reach critically low levels during massive obstetric hemorrhage, and a fibrinogen concentration below 2 g/L is a highly predictive marker for severe PPH progression[54,55]. Cryoprecipitate provides fibrinogen along with Factor VIII, von Willebrand factor, and Factor XIII, but requires 20–30 minutes thaw time and carries transfusion-transmitted infection risk.

Fibrinogen concentrate (FC), a virally inactivated lyophilized powder stored at room temperature, enables precise dosing and immediate reconstitution, and has gained favor in many centers despite ongoing debate regarding optimal replacement strategy[54,55]
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**Massive Transfusion Protocols and Recombinant Factor VIIa:** Massive transfusion protocols (MTP) provide structured algorithms for rapid blood product delivery, targeting the 'lethal triad' of hypothermia, acidosis, and coagulopathy. Most protocols employ a 1:1:1 ratio of packed red blood cells to fresh frozen plasma to platelets, with therapeutic targets of hemoglobin >8 g/dL, platelets >50,000/µL, and fibrinogen >2 g/L[54,56,57].

Recombinant activated Factor VII (rFVIIa) initiates a 'thrombin burst' at injury sites and has been employed as a rescue therapy for life-threatening PPH refractory to conventional measures[41,58].

However, randomized trials demonstrate only moderate reduction in blood product consumption without proven survival benefit, and a significant risk of arterial and venous thromboembolic events limits its use. Current guidance restricts rFVIIa to cases where conventional interventions—including uterotonics, TXA, surgical procedures, and adequate blood product replacement—have failed, and after correction of acidosis, hypothermia, thrombocytopenia, and fibrinogen deficiency[41,59].

**Fluid Resuscitation and Cell Salvage:** Isotonic crystalloids (Ringer's lactate preferred) are recommended as first-line fluids for initial resuscitation, not exceeding 2,000 mL before transitioning to blood products in active hemorrhage[9,54]. Excessive crystalloid administration risks dilutional coagulopathy and may disrupt formed clots through elevated blood pressure before definitive hemostasis is achieved.

Intraoperative cell salvage, historically avoided in obstetrics due to theoretical amniotic fluid contamination concerns, has been validated as safe by the SALVO trial (2017), which demonstrated no increase in adverse maternal outcomes with appropriate leukocyte depletion filtration[60,61]. While routine use did not significantly reduce donor blood requirements in the overall population, subgroup analyses suggested benefit in high-risk cases and blood-scarce settings.

## INTEGRATED CARE BUNDLES AND PROTOCOLS

**The WHO First-Line Bundle and E-MOTIVE Protocol:** The World Health Organization first-line treatment bundle comprises five concurrent actions initiated immediately upon PPH diagnosis: (1) uterine massage; (2) administration of oxytocic drugs; (3) administration of tranexamic acid; (4) intravenous fluid resuscitation; and (5) thorough genital tract examination[1,56]. This simultaneous multi-intervention approach addresses multiple pathophysiological mechanisms concurrently, in contrast to traditional sequential escalation that allowed coagulopathy and hemodynamic instability to progress between each intervention attempt.

The landmark E-MOTIVE trial (2023)—a cluster-randomized trial involving over 200,000 women across multiple countries—demonstrated that implementation of this protocol, incorporating early detection using calibrated drapes, reduced the risk of severe PPH (blood loss ≥1,000 mL) or maternal death by 60% compared to usual care[1].

Critically, the intervention increased use of first-line treatments without increasing second-line interventions such as balloon tamponade or surgery, confirming that earlier and more comprehensive initial therapy reduces the need for escalated measures.

**Quantified Blood Loss and Escalation Triggers:** Quantified blood loss (QBL) measurement—combining calibrated conical drapes and gravimetric weighing of soiled materials—enables early and accurate hemorrhage identification, overcoming the 35–50% systematic underestimation of visual assessment[1,62]. The Shock Index (SI = heart rate ÷ systolic blood pressure), with values above 1.0 indicating significant hemodynamic compromise and above 1.5 indicating severe shock, provides a practical bedside parameter for triggering escalation independent of individual vital sign thresholds[4,63].

Stage-based management protocols categorize PPH into sequential stages with specific action items: Stage 1 (500–1,000 mL) triggers basic interventions; Stage 2 (1,000–1,500 mL or ongoing bleeding) escalates to TXA, additional uterotonics, and transfusion preparation; Stage 3 (>1,500 mL or hemodynamic instability) activates MTP, balloon tamponade, and notification of surgical and interventional radiology teams; Stage 4 defines criteria for definitive surgical intervention[64].

**Simulation-Based Training:** The implementation of complex PPH protocols depends critically on multidisciplinary team preparation. In situ simulation training—employing realistic mannequin-based scenarios in the actual clinical environment—reduces clinician stress, enhances self-efficacy, and improves team communication during actual emergencies[37,65]. Clinical evidence demonstrates significant reductions in the utilization of five or more blood product units, decreased time to intervention, and overall maternal morbidity reduction following regular simulation training programs[37,66].

## SPECIAL POPULATIONS AND CLINICAL CONTEXTS

**Low-Resource Settings:** Managing PPH in low-resource settings (LRS)—where 99% of global PPH deaths occur—requires adaptation of protocols to available infrastructure, with emphasis on low-cost, heat-stable, and easily deployable interventions[34,67]. Misoprostol assumes central importance as a thermostable orally administrable uterotonic requiring neither cold-chain storage nor injection equipment[12,68].

The 'family first aid' model—advance distribution of misoprostol (600 µg) for self-administration by pregnant women during home births—has demonstrated safety and increased timely prophylaxis coverage in rural Pakistan[23].

Condom-catheter tamponade provides critically important second-line capability for facilities without surgical capacity, with training packages developed for midwives and birth attendants enabling effective deployment[27,69]. The NASG is particularly valuable for stabilization during transport from primary care facilities to referral centers[52]. Regardless of initial success with these interventions, the 2021 WHO guidance emphasizes that optimal outcomes require that UBT be implemented within systems that also provide access to referral and definitive surgical care when needed[13].

**Cesarean Delivery and Abnormal Placentation:** During cesarean delivery, intraoperative UBT can be placed transabdominally through the uterine incision before closure; inflation volume should be reduced to 250–300 mL to avoid tension on the hysterorrhaphy[18,28]. The 'uterine sandwich' technique—combining intrauterine balloon tamponade with uterine compression sutures—provides mechanical compression from both internal and external surfaces for refractory hemorrhage[18,70].

Placenta accreta spectrum (PAS) disorders require coordinated multidisciplinary management, with UAE serving dual prophylactic and therapeutic roles[5,41,71]. Resuscitative endovascular balloon occlusion of the aorta (REBOA)—percutaneous insertion of a balloon catheter via femoral artery access with aortic occlusion providing immediate hemodynamic stabilization—has been described in case reports as a rescue technique for exsanguinating PPH, creating time for definitive surgical or radiological intervention[72].

**Patients Declining Blood Products:** Management of PPH in patients declining allogeneic transfusion—most commonly Jehovah's Witnesses—requires proactive antenatal planning and aggressive non-surgical hemostatic management[41,54,73]. Early identification, detailed documentation of acceptable interventions (including cell salvage, albumin, and clotting factor

Table 3: Evidence Summary: Key Non-Surgical Interventions for PPH Management

| Intervention | Level of Evidence | Key Outcome | WHO Recommendation |
|---|---|---|---|
| Oxytocin prophylaxis (AMTSL) | Level I (multiple RCTs) | 50% reduction in PPH | Strong – universal standard incidence |
| Heat-stable carbetocin | Level I (CHAMPION RCT) | Non-inferior to oxytocin; | Recommended in LRS heat-stable |
| Tranexamic acid (TXA) | Level I (WOMAN trial, n>20,000) | 19–31% reduction in death | Strong – first-line bundle from bleeding |
| Uterine balloon tamponade | Level II (systematic reviews) | 80–98% success; 56% lower | Conditional – second-line hysterectomy OR |
| Condom-catheter tamponade | Level II–III | 88–96% success; USD | Recommended for LRS 1/DALY averted |
| Uterine artery embolization | Level II (cohort studies) | 90–98% hemorrhage control | Selected cases with IR access |
| NASG | Level II (clinical trials) | 38–54% mortality reduction; shock reversal | Recommended for LRS transport |
| E-MOTIVE bundle | Level I (cluster RCT, n>200,000) | 60% reduction in severe | Strong – bundled approach PPH/death |

RCT: Randomized controlled trial, LRS: Low-resource settings, IR: Interventional radiology, DALY: Disability-adjusted life-year, NASG: non-pneumatic anti-shock garment, AMTSL: Active management of third stage of labour

concentrates), anemia correction through erythropoietin and IV iron, and early aggressive deployment of TXA, fibrinogen concentrate, and the NASG are essential components of care.

## OUTCOMES, EVIDENCE QUALITY, AND COST-EFFECTIVENESS

**Hysterectomy-Sparing Rates and Maternal Mortality:** A comprehensive network meta-analysis found that UBT was associated with a 56% lower risk of hysterectomy (OR 0.44) compared to surgical controls, while UAE demonstrated a 26% lower risk (OR 0.74)[20]. Standardized care bundles reduced hysterectomy rates from 27.27% to 11.54% following institutional implementation—a reduction exceeding 50%[48,56]. Systemic implementation of UBT and UAE protocols has reduced emergency peripartum hysterectomy rates below 5% of all PPH cases in tertiary referral centers, compared to historical rates exceeding 15–20% (Table 3)[4,74].

The WOMAN trial—the largest randomized trial in obstetric hemorrhage—established TXA as providing 19–31% mortality reduction from bleeding, consistent across subgroups of hemorrhage etiology, delivery mode, and geographic region[9]. In low-resource settings, NASG application during stabilization reduces maternal mortality by 38–54%[52]. The E-MOTIVE protocol achieves a 60% reduction in severe PPH outcomes and mortality [1].

**Fertility Preservation and Subsequent Pregnancies:** Return of normal menses occurs in nearly 100% of patients within 2–3 months following UAE[32,40,46]. Successful live births have been documented in 50–71% of women attempting conception after UAE for PPH, though increased risks of preterm delivery (12–25%), fetal growth restriction (10–15%), and placental abnormalities require enhanced antenatal surveillance[32,46]. UBT appears to have minimal impact on subsequent fertility given its mechanical, non-vascular mechanism.

**Cost-Effectiveness:** TXA at approximately USD 1–4 per dose with demonstrated mortality reduction meets cost-effectiveness thresholds in virtually all healthcare settings[9,54]. Condom-catheter tamponade at USD 1.00 per DALY averted represents extraordinary healthcare value. Commercial UBT devices (USD 300–400) and UAE (substantial institutional infrastructure investment) are cost-effective in high-resource settings but require alternative strategies in LRS[22,27].

## FUTURE DIRECTIONS AND EMERGING THERAPIES

**Novel Devices: The Jada System:** The Jada System represents a fundamentally novel approach to hemorrhage control, applying low-level vacuum (60–80 mmHg) to collapse the uterine cavity and facilitate myometrial contraction, mimicking physiological uterine retraction rather than applying outward distending pressure[14]. A pivotal study demonstrated successful control of abnormal postpartum uterine bleeding in 94.6% of participants with a median time to hemorrhage control of approximately 3 minutes[14]. Comparative trials are needed to define the relative efficacy against conventional balloon tamponade.

**Topical Hemostatic Agents and Point-of-Care Diagnostics:** Chitosan-based agents (e.g., Celox™), hemostatic sponges, and topical thrombin preparations offer potential for localized hemorrhage control with minimal systemic effects[10,41]. Intrauterine application of chitosan-covered gauze has demonstrated efficacy comparable to conventional devices in case series. Viscoelastic point-of-care testing (TEG, ROTEM) enables real-time assessment of clot formation kinetics, clot strength, and fibrinolysis within 15–20 minutes—substantially faster than conventional laboratory testing—facilitating goal-directed hemostatic resuscitation and potentially reducing unnecessary transfusion[41,75].

**Artificial Intelligence and Predictive Algorithms:** Machine learning algorithms incorporating multiple antepartum and intrapartum variables can predict PPH with greater accuracy than conventional risk scoring, potentially enabling proactive preparation before hemorrhage develops[3,37]. The Triton™ system applies computer vision to estimate blood loss from images of surgical sponges and suction canisters, addressing the persistent problem of subjective underestimation without labor-intensive gravimetric measurement[1,37]. These technologies remain under investigation but represent promising directions for improving early recognition and response.

## CONCLUSIONS

**Summary of Key Findings:** This review has examined the evidence supporting non-surgical interventions for PPH management, demonstrating a clear paradigm shift toward uterine-preserving, conservative approaches backed by progressively robust evidence. The non-surgical triad of tranexamic acid, uterine balloon tamponade, and uterine artery embolization forms the foundation of contemporary management[9,21,40]. TXA, validated by the WOMAN trial, provides a 19–31% reduction in death from bleeding [9]; UBT achieves hemostasis in 80–98% of cases[21,41]; UAE demonstrates efficacy exceeding 90–98% for refractory hemorrhage while preserving fertility in 50–71% of women attempting subsequent conception[40,46].

The E-MOTIVE protocol, through simultaneous bundled deployment of multiple evidence-based measures guided by objective blood loss quantification, achieves a 60% reduction in severe PPH and maternal death—demonstrating that the organization and timing of care delivery may be as important as the specific interventions employed[1,56].

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**Clinical Recommendations:** Based on evidence reviewed herein, key recommendations for practice include:

- Implement standardized PPH protocols incorporating the WHO first-line bundle (uterine massage, uterotonics, TXA, IV fluids, and genital tract examination) as simultaneous concurrent measures at first recognition of significant hemorrhage.
- Adopt quantified blood loss measurement using calibrated drapes and gravimetric methods universally in all delivery settings.
- Ensure universal access to TXA in all facilities providing delivery care; maintain on immediate-access stock at all birth locations.
- Train all birth attendants in UBT insertion, including improvised condom-catheter methods, and make these materials available at all delivery sites.
- Establish referral pathways to facilities with interventional radiology capabilities; consider prophylactic intra-arterial catheterization for known high-risk PAS cases.
- Conduct regular multidisciplinary simulation training with in situ scenarios and structured debriefing.
- Optimize antenatal care through systematic anemia correction, structured risk stratification, and multidisciplinary planning for identified high-risk cases.

**concluding statement:** Postpartum hemorrhage remains a leading cause of maternal mortality worldwide, yet the majority of deaths are preventable through timely application of evidence-based interventions. The evolution from a surgical-dominant paradigm to stepwise conservative management represents one of the most significant advances in obstetric care. The challenge now lies in ensuring these interventions reach all women regardless of geographic location or economic circumstance. The stark disparity in PPH-related mortality between high-resource and low-resource settings reflects not a lack of effective interventions, but failures in access, training, and health systems capacity. Addressing this disparity requires sustained investment in infrastructure, training, and supply chains, combined with continued innovation in technologies appropriate for resource-limited environments.

Every woman deserves access to safe childbirth and effective management of complications. The evidence reviewed herein demonstrates that non-surgical interventions—when implemented within organized care systems—can transform PPH from a leading cause of maternal death to a manageable complication. The remaining task is to translate this evidence into universal practice.

## DECLARATIONS

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