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Review Article

Updates on postpartum hemorrhage: prediction, early detection and management

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ABSTRACT

Postpartum hemorrhage (PPH) continues to pose a significant threat to maternal health worldwide, despite advancements in obstetric care. This article provides an overview of recent updates in the management of PPH, focusing on strategies aimed at enhancing outcomes and minimizing complications. Current guidelines underscore the importance of early identification and immediate intervention in the management of PPH. Machine learning models (MLMs), E-motive approach, estimation of serum fibrinogen levels and ABL estimation Active management protocols advocate for the administration of carbetocin and use of negative intrauterine pressuresuction device in high-risk cases to mitigate blood loss. In cases where initial pharmacological interventions fail to control bleeding, alternative measures such as balloon tamponade or uterine artery embolization (UAE) may be necessary. Innovations like the Bakri balloon, NASG, UAE have revolutionized the management of atonic PPH by offering a non-surgical option for hemorrhage control. Permissive resuscitation, recombinant active factor seven (VIIa), desmopressin acetate (DDAVP) and lyophilized fibrinogen concentrate have proven to be beneficial in refractory PPH. Efforts are ongoing to develop less invasive techniques that prioritize maternal fertility and minimize morbidity. Furthermore, the integration of multidisciplinary teams and simulation training plays a pivotal role in enhancing PPH management.

Keywords: Postpartum haemorrhage, Early detection, Updates, Prevention, E-motive

INTRODUCTION

Postpartum hemorrhage (PPH) remains a significant cause of maternal mortality and morbidity globally, resulting in the death of a woman approximately every 10 minutes.[1] It is an unpredictable obstetric emergency resulting in an annual 70,000 maternal deaths worldwide (WHO 2023). While the incidence of PPH has decreased over time, it continues to present a formidable challenge for obstetricians and imposes substantial physical, emotional, and socioeconomic burdens on families.

The world health organization (WHO) defines PPH as "blood loss equal to or exceeding 500 mlwithin 24 hours after childbirth," regardless of delivery mode, and severe PPH as "blood loss equal to or exceeding 1000 ml within 24 hours of delivery". "The 4Ts-tone, trauma, tissue, and thrombin" introduced by the American academy of family physicians in the American life support in obstetrics (ALSO) summarize the primary causes of PPH. While most patients respond well to initial treatments for PPH, such as uterotonics, uterine massage, and tranexamic acid, approximately 10-20% do not achieve adequate response to these measures. This subset, known as refractory PPH, constitutes the majority of PPH-related morbidity and mortality.[2] Early diagnosis, adequate resources, and skilled health care providers and care teams are crucialfor optimizing the management of refractory PPH to mitigate

severe maternal morbidity and mortality.

SECTION A: NEWER APPROACH FOR IDENTIFICATION OF HIGH-RISK CASES

MLMs

Advancements in computer science have propelled the evolution of artificial intelligence (AI). MLM is a subset of AI that uses algorithms and data, learns from patterns and makes predictions. Unlike traditional programming algorithms, AI can derive rules and patterns from both input and output data. It provides individualized risk assessment to stratify patients and helps to implement preventive and therapeutic interventions. Numerous studies have been conducted to develop predictive models using AI, demonstrating their superiority in terms of accuracy, sensitivity and specificity over traditional prediction models.

A 2-phase study comprising 1.5 lakh patients developed two MLMs considering 55 risk factorsalready known for PPH. The extreme gradient boosting model (MLM) had the best discriminativeability to predict PPH.[3] Another 5-year study comprising 9894 women used 11 clinical variables to predict PPH. Five machine learning classifiers: logistic regression, support vector machine, random forest, boosting trees, and decision tree were used and reported high accuracy in PPH prediction.[4] A 2023 machine learning-based study of 2550 births reported severe PPH in 40 women (2.5%), which was accurately predicted with a machine learning model.[5]

E-motive approach

The E-motive trial, conducted by researchers from WHO and university of Birmingham has proven to be a breakthrough in reducing deaths from childbirth-related bleeding. It was carried out across four countries in 80 secondary level hospitals involving over 2 lakh patients.[6]

It aims to eliminate the three common delays: failure to recognize PPH early enough, lack of preparation and the wait-and-see approach typically taken to treatment. We administer one drug and wait for its response while the patient continues to bleed, and if access to services like blood transfusion or surgery is limited, she may quickly land in critical condition.

E-motive package (Figure 1) incorporates: Early and precise identification of PPH using blood-collection drape. It involvesobjective blood loss measurement every 15 min during 1st hour of delivery. Immediate and simultaneous treatment regimen, including uterine massage, uterotonics, intravenous fluid administration, thorough examination, and, if necessary, referral toadvanced care.

The timely detection of PPH and implementation of bundled treatment significantly reduced blood loss and maternal mortality. PPH detection rates improved from 51% to 91%. The need for laparotomy for PPH decreased by an astounding 60%.[7]

WHO advises incorporating the E-motive intervention into comprehensive strategy that includes customized training, supplying PPH equipment, engaging local champions, conducting regular audits, and providing feedback.

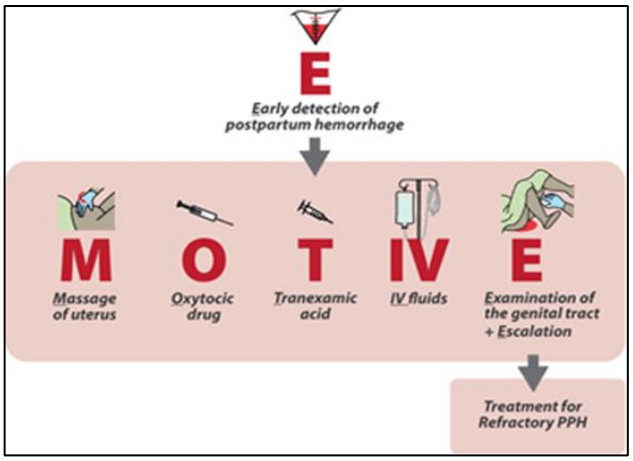

Figure 1: The E-motive intervention.

Serum fibrinogen levels

Fibrinogen, a plasma glycoprotein, is integral to hemostasis and is involved in the final process of coagulation cascade. Fibrinogen levels increase with advancing pregnancy and reach a peak (~5 gm/L) in the third trimester of pregnancy and decreases in the postpartum period.

Studies have suggested that the limiting concentration of fibrinogen to maintain adequatehemostasis is 200 mg/dL. When fibrinogen values drop to <100 mg/dL they are associated with the loss of 1.4 blood volumes, establishing a relationship between fibrinogen values and the severity of PPH.[8]

Low fibrinogen levels are associated with increased incidence of primary PPH. Zero-hour fibrinogen levels correlate significantly with the aggravation of primary PPH and levels <2 gm/L serve as a predictor for progression to severe PPH.[9,10]

Accurate blood loss estimation

Accurate blood loss measurement during the third stage of labor is crucial for prompt diagnosis and management of PPH, ensuring timely intervention which is critical for maternal safety. Immediate monitoring of vaginal bleeding, uterine fundal height, maternal blood pressure, and pulse every 15 minutes initially, followed by hourly checks for the next 5 hours, is essential post-birth.

Visual estimation of blood loss (VEBL) often underestimates actual amounts, whereas quantitative

methods like gravimetric (weighing swabs) or volumetric (collecting blood in containers, calibrated drapes) (Figure 2) provide more accurate assessments.[11]

Figure 2: Calibrated drape.

Studies indicate a 30% error rate with VEBL compared to gravimetric techniques and recent research notes a tendency to overestimate blood loss among providers.[12]

Recent AI advancements utilize mobile technology and image recognition to enhance blood loss measurement accuracy (Triton system). AI systems capture images of surgical materials using tablet cameras, conduct colorimetric analyses via mobile apps (Figure 3), and use cloud-based machine learning to provide real-time quantification of hemoglobin levels and blood loss.[13]

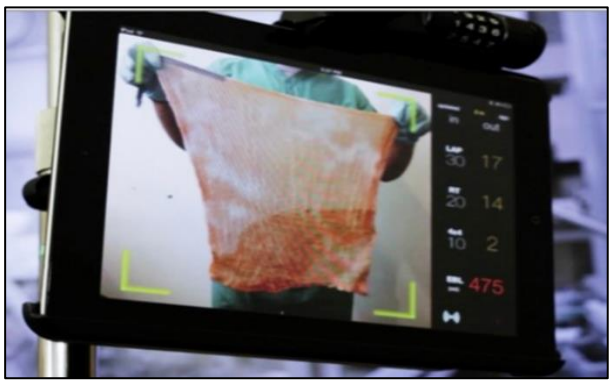

Figure 3: Triton system (AI mobile app).

AI has shown greater sensitivity in detecting blood loss exceeding 1,000 mL compared to traditional methods. Colorimetric estimation aligns closely with reference volumes, surpassing the accuracy of visual and gravimetric approaches.[14] ACOG supports quantitative methods for their superior accuracy over visual estimation and recommends their inclusion in standardized protocols for both vaginal and cesarean deliveries, ideally developed by multidisciplinary teams.

Checklist by WHO

The WHO's "safe childbirth checklist and implementation guide," aims to address key causes ofmaternal and newborn morbidity and mortality, including PPH and infection. The checklist targets four critical points in clinical care across a healthcare worker's workflow: upon admission, before pushing or cesarean section, within one-hour post-birth, and before discharge of mother and newborn. These checkpoints facilitate timely checks to prevent complications and align with global efforts to reduce maternal mortality.[15] The checklist presents a structured compilation of evidence-based essential birthing procedures aimed at addressing the primary causes of maternal mortality worldwide.

Initially piloted in 9 countries in Africa and Asia, the checklist was later field tested in KarnatakaState, India, where adherence to recommended practices significantly increased. In India, the government of India recommends integrating this checklist with PPH management under DAKSHATA, national health mission. Recent studies in 2024 indicate that consistent use of thechecklist correlates with higher intervention rates and reduced blood loss. [16]

Early detection of severe PPH-shock indexindicator

The shock index (SI), calculated as heart rate (HR) divided by systolic blood pressure (SBP), serves as an indicator of hemodynamic stability. Initially proposed for non-pregnant women, SI has been found effective in assessing hemodynamic compromise in obstetric patients as well.

SI, along with the rule of 30, aids clinicians in emergencies by assessing blood loss andhemodynamic instability. The rule of 30 defines blood loss as approximately 30% of normal volume, marked by a 30% decrease in hematocrit and hemoglobin, a 30 mm Hg decrease in SBP, and a 30 bpm increase in pulse rate.

Studies on SI in PPH compared to conventional parameters showpromising results. Nathan et al suggest SI thresholds of >0.9 for referral and ≥1.7 for urgent intervention to swiftly detect and manage obstetric shock, particularly in resource-limited settings.[17] In low-resource settings, an SI >0.9 indicates referralnecessity, while SI ≥1.4 necessitates urgent intervention in tertiary care, enhancing specificity (80.7%-90.8%) without compromising negative predictive value (88.8%-98.5%) for adverse outcomes.[18] The obstetric SI norm ranges 0.7-0.9, differing from non-pregnant norms due to pregnancy related hemodynamic changes hindering hypovolemia detection.[19] FIGO recommends SI use in PPH diagnosis and management, considering SI >0.9 as indicative of severe PPH and hemodynamic instability.

Training of healthcare providers by structured instruction model

Simulation provides immersive, guided experiences aimed

at replicating real-world aspects interactively, enhancing healthcare professionals' knowledge, skills, and attitudes while ensuringpatient safety. Simulated scenarios, such as PPH, identify gaps in knowledgeand performance without patient risk, boosting learner confidence in managing unexpected events. In healthcare education, simulation is pivotal, improving resident training and recommended by accreditation bodies to enhance patient care and safety. Recent studies, like one on OBGY providers in 2022, demonstrate improved proficiency in procedures like B-lynchsutures and UBT through simulation-based training.[20] The joint commission on accreditation of healthcare organizations emphasizes clinical drills to enhance maternal hemorrhage management without specifying exact implementation methods.[21]

SECTION B: DEVELOPMENTS IN PPH PROPHYLAXIS

Carbetocin

Carbetocin, a heat-stable, long-acting synthetic analog of oxytocin, is recommended at a dose of 100 mcg for preventing PPH, administered intramuscularly or slowly intravenously. It is contraindicated in women with cardiovascular disorders, epilepsy, liver or kidney disease, or known hypersensitivity to carbetocin. The stability of carbetocin as a room- temperature formulation has been verified at various temperatures: 30°C for 3 years, 40°C for 6 months, 50°C for 3 months, and 60°C for 1 month.[22]

The 2018 WHO champion trial found carbetocin to be as effective as oxytocin in preventing blood loss ≥500 ml.[23] Elbohoty et al found that carbetocin, compared to oxytocin and misoprostol, significantly reduced the need for additional uterotonics following elective cesarean delivery.[24] Carbetocin has a low adverse effect profile comparable to oxytocin and effectiveness similar to syntometrine, positioning it as a viable alternative for preventing PPH. Moreover, in comparison with misoprostol, carbetocin showed superior efficacy in reducing blood loss, shortening the third stage of labor, minimizing adverse effects, and decreasing the requirement for additional uterotonic drugs, as confirmed by subsequent trials.[25]

WHO recommends the use of carbetocin as an alternative to oxytocin where the cost is comparable. Owing to decreased requirement for additional uterotonics compared to oxytocin, carbetocin is being recommended during elective cesarean section by the national institute for health and care-excellence (NICE, 2023).

Negative intrauterine pressure suction device

Using a suction cannula to create negative intrauterine pressure is a cost-effective method for managing atonic PPH, particularly in low- and middle-income countries (LMICs), addressing challenges related to affordability and accessibility of uterotonics.

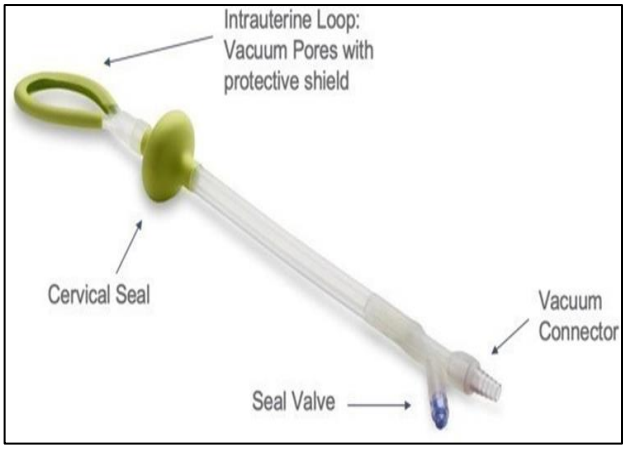

Figure 4: The JADA system.

The JADA system

The Jada system (Figure 4), FDA-approved in 2020 for managing atonic PPH, comprises a flexible silicone intrauterine loop with vacuum pores, protected by a cover and cervical seal. It is insertedtransvaginally and manually for all delivery modes. Removal timing ranges from 1.5 to 24 hours post-placement, with suction cessation after 60 minutes and a subsequent 30-minute period withoutsuction post-removal. Initial studies showed a 94% success rate in bleeding control within a median of 3 minutes, with 98% of providers finding it easy to use and 97% willing to recommendit.[26] The 2020 RUBY trial reported success rates of 95.8% for vaginal births and 88.2% for cesarean births, with mean indwelling times of 4.6 hours and 6.3 hours, respectively.[27]

Suction tube uterine tamponade (STUT)

The flexible and round-tipped Levin stomach tube (Figure 5), ranging from FG24 to FG36, is manually inserted into the uterine cavity until the proximal side hole extends at least 5 cm beyond the cervix. It is then secured and connected to external suction tubing with pressures of 100 to 200mm Hg. Successful use of the STUT method is maintained for 1 hour, followed by a 20-minute monitoring period without suction before removal.[28] It can successfully avert laparotomy in refractory PPH cases.

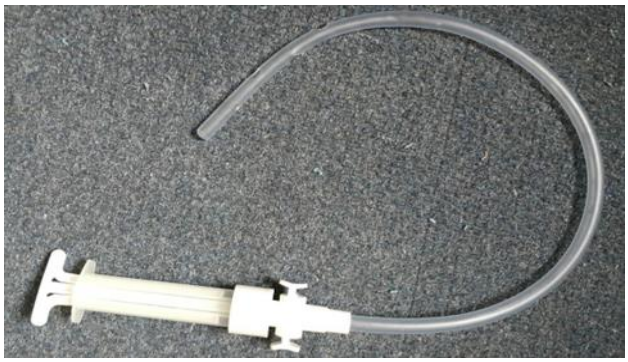

Figure 5: Suction tube uterine tamponade.

Rigid uterine retraction cannulas/ Panicker's suction cannula/ SR suction cannula

These are innovative Indian devices. The Panicker cannula (Figure 6), made of stainless steel or plastic, measures 25 cm in length and 12 to 18 mm in width. It features perforations for suction using a bottle or vacuum extraction pump up to 650 mm Hg, typically left in place for 30 minutes.The SR suction cannula, made of stainless steel and available in various lengths, is selected based on uterine size and delivery mode. It is inserted via the vagina into the uterus to reach the fundus and connected to a suction apparatus maintaining negative pressure of 650 mm Hg for 15 minutes.In an initial study of 20 PPH patients unresponsive to oxytocin and another uterotonic, the cannula effectively controlled bleeding within 3 minutes.[29] It effectively controls bleeding in refractory PPH cases. Sharma et al reported a significant reduction in average blood loss during vaginal delivery and a 75% decrease in atonic PPH incidence after implementing the negative intrauterine-pressure suction device (NIPSD) alongside routine active management of third stage of labor (AMTSL).[26]

Figure 6: The Panicker cannula.

Uterine balloon tamponade

Uterine balloon tamponade (UBT) serves dual roles in diagnosing and treating PPH. It acts by stimulating uterine receptors to trigger contractions and applying hydrostatic pressure against bleeding sinuses. When UBT pressure matches systolic arterialpressure at the bleeding site, it achieves tamponade. Early UBT placement is crucial during PPH emergencies, requiring skilled providers to minimize positioning risks.

Uterine balloon devices (Figure 7) are categorized into two groups: Fixed volume devices: condom uterine balloons (such as ESM-UBT kit, CG balloon),Bakri balloon, Rusch balloon, and the Ebb system.[30] Free flow devices: glove balloon, Ellavi UBT, and Zukovski balloon.[31]

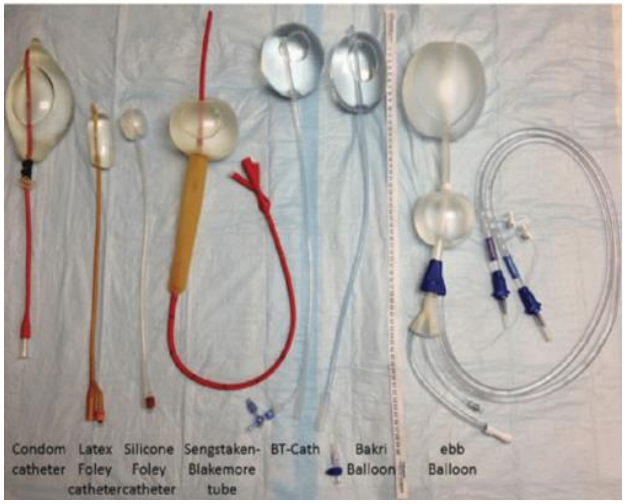

Figure 7: UBT devices.

The need for a drainage port in UBT devices remains debatable due to potential clotting. Given that most bleeding originates from the placental site occupying only 20% of the uterine cavity, port proximity to the source is uncertain. Studies show UBT insertion before severe shock ensures nearly 100% survival in uncontrolled atonic PPH cases.[32] A 2020 meta-analysis reported an overall UBT success rate of 85.9%, higher for uterine atony and placenta previa but lower for placenta accreta and retained products.[33] Safety trials with condom UBT devices in Africa found no increased infection risks or adverse reproductive impacts compared to Bakri balloons.[30] Complications from UBT are infrequent and do not affect future reproductive health. Overall, UBT achieves success rates of 83% to 95%, with almost complete survival when inserted before severe shock.[34] Integrated into PPH pathways, UBT in high-income countries reduces hysterectomy rates and invasive procedures like artery ligation or embolization.[35]

Uterine artery embolization

UAE involves catheterizing arteries and blocking them with polyvinyl alcohol (PVA) particles (150-300 microns), mimicking vessel ligation. PVA particles are typically absorbed within 10 days, allowing vessel recanalization. It's considered for stable patients with persistent bleeding or planned elective surgery for placenta accreta spectrum.

It offers high success rates, minimal invasiveness, fertility preservation, and effectiveness in challenging surgical scenarios. Success rates exceed 90% with an 8.7% complication rate.[36] Common complications include low-grade fever, pelvic infection, groin hematoma, and temporaryischemia. Additional complications like uterine artery dissection, hematoma, paresthesia, and limbedema have been reported. In a meta-analysis of 6 RCTs and 9 observational studies, UAE significantly reduced blood loss, operating times, and hospital stays compared to hysterectomy forrefractory PPH.[37]

Medical drones/UAVS

Currently, the primary methods of medical product transport include ground (e.g., ambulances, cars) and air (e.g., helicopters, airplanes) transportation. Globally, unmanned aerial vehicles (UAVs) or drones (Figure 8) are increasingly employed to improve mobility across challenging geographical terrains, reduce carbon emissions, and potentially enhance healthcare service cost-effectiveness. This requires collaboration across medical, engineering, and health economics disciplines.

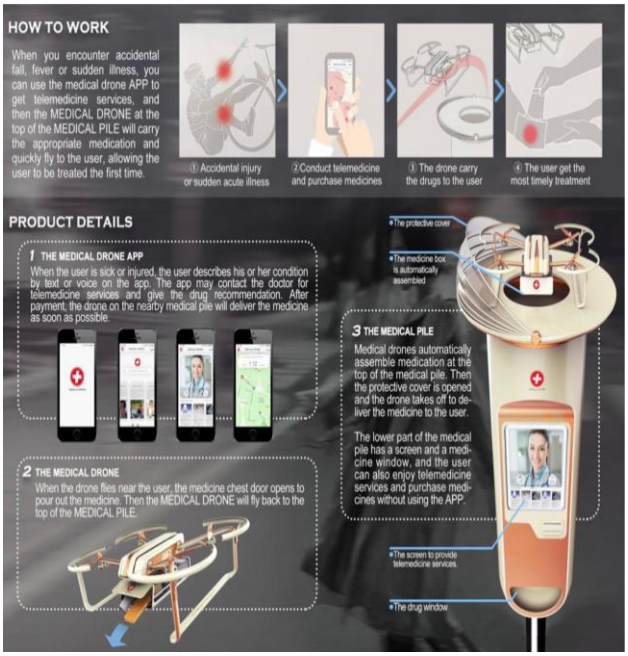

Figure 8: Working of the medical drone.

Drones are used globally to address critical issues such as access to medicines, vaccines, blood samples, and biological sample collection in underdeveloped regions. They enhance accessibility by reaching remote populations, delivering life-saving medical services where traditional healthcare facilities are lacking. Developed countries have integrated drones into public health departments to improve patient care.[38]

In India, initiatives like 'medicines from the sky' with the world economic forum aim to revolutionize healthcare supply chains by using drones to deliver vaccines, diagnostic samples, and medications to remote areas.[39] During the COVID-19 pandemic, the 'i-DRONE' project by the ICMR delivered vaccines to inaccessible regions. The 'project dronaid' at JIPMER, Puducherry, under MOHFW guidance, aims to facilitate community-level clinical applications and emergencyservices in two trial phases. Despite their potential, drones in healthcare face practical challenges such as short battery life, slow speed, limited payload, weather sensitivity, pilot shortages, security risks, societal acceptance, and technological limitations.

SECTION C: DEVELOPMENTS IN DRUG TREATMENT/ MEDICO-SURGICAL APPROACH

Non-pneumatic anti-shock garment

The non-pneumatic anti-shock garment (NASG) is an affordable compression device for refractory PPH, originally derived from NASA technology used to prevent astronauts from blacking out during extreme acceleration. It applies external pressure to the lower body using neoprene and Velcro, comprising six segments (Figure 9) that provide circumferential counterpressure to improve cardiac output and blood pressure.

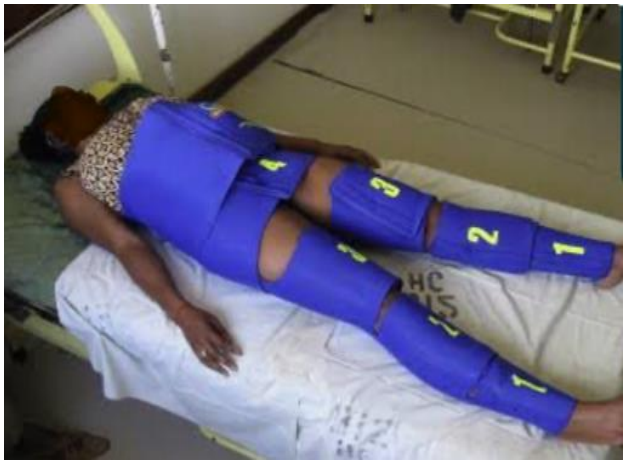

Figure 9: NASG.

The garment's pressure (20-40 mmHg) reduces vascular space in the lower body, decreasing pelvic perfusion and promoting hemorrhage control. It enhances cardiac output and central circulation, directing blood flow to vital organs, facilitating rapid shock recovery.[40] NASG is suitable for women with PPH showing signs of shock or hemodynamic instability, serving as a temporary measure until definitive treatment is administered.

During application, segments are tightly closed from ankles to abdomen, preserving joint mobility and adjusting pressure to maintain respiration. For surgical needs, abdominal and pelvic segmentscan be temporarily opened, ensuring careful monitoring for blood pressure changes. Continuous monitoring is crucial, and NASG can be used safely for up to 48 hours, though longer durations have been reported.[41]

Removal requires stable vital signs (blood loss <50 ml/h, HR <100 bpm, SBP ≥100 mmHg for 2 hours), with segments opened sequentially from ankle end and monitored for stability or signs of bleeding. If vital signs deteriorate or bleeding resumes, segments are promptly closed. NASG is reusable and should be laundered after use, with a lifespan of up to 144 washes.

Observational quasi-experimental studies at referral centers in Egypt, Nigeria, India, Zambia, andZimbabwe

showed a 48% drop in maternal mortality related to hypovolemic shock secondary to PPH.[41] NASG combined with standard PPH care reduces maternal mortality as well as combined adverse outcomes. Another study in 2022 showed that blood loss (>750 ml) decreased from 81.3% to 50% after the use of NASG, thus lowering the number of women requiring blood transfusion. NASG shows promise for the management of obstetric haemorrhage, particularly in lower resource settings.[42]

Currently, there are no absolute medical contraindications for NASG use and it is used in over 50countries world-wide, and it has been recommended in many national and international guidelinessuch as GLOWM, WHO, FIGO, and others.[43] NASG is included in the WHO, UNICEF, and United Nation's Population Fund (UNFPA) interagency list of medical devices for essential interventions for reproductive, maternal, newborn and child health (2015).

Fibrinogen concentrates

Fibrinogen is crucial for effective hemostasis. Its levels correlate with the severity of PPH, but measuring them is time-consuming, limiting their use during ongoing PPH. Recommendations from societies like RCOG and the European society of anesthesiology suggest early administration when fibrinogen levels are <2 g/dL.[44] Fibrinogen concentrate, a virally inactivated lyophilized powder stored at room temperature, requires no thawing or blood typing and rapidly restores fibrinogen levels. Studies have shown that administering 1 to 4 gm of fibrinogen significantly reduces the need for blood transfusion.[45] The FIB-PPH, OBS2 and FIDEL trials found no benefit in clinical outcomes with fibrinogen concentrate treatment when fibrinogen levelswere adequate.[46]

Recent studies suggest fibrinogen concentrate efficiently achieves hemostasis in PPH. Early administration can be beneficial in the absence of viscoelastic measurements like thromboelastography, especially if fibrinogen levels are <2 g/l.[47] Fibrinogen concentrate advantages include easy administration, convenient storage, standardized fibrinogen content, and low risks of complications like transfusion-transmitted infection and transfusion-related acute lunginjury.

Recombinant activated factor VII

Recombinant activated factor VII (rFVIIa), marketed as NovoSeven® by Novo Nordisk A/S, is a significant advancement in managing severe PPH. Initially developed for hemophilia, rFVIIa hasemerged as a therapy for life-threatening PPH refractory to standard treatments, potentially averting the need for peripartum hysterectomy. It induces hemostasis by binding to tissue factor and activating factor X directly on activated platelets at the injury site. rFVIIa, a recombinant product, mitigates concerns related to blood scarcity and viral transmission risk, being devoid of human proteins. It offers localized hemostasis with minimal thrombogenicityand low risk of anaphylaxis or immune responses. However, its short half-life necessitates frequentdosing and it lacks a measurable laboratory parameter for efficacy, relying solely on subjective judgment.[48] The recommended dose is 90 mcg/kg IV over 3-5 minutes, with potential repeat dosing if necessary. Before administration, hemoglobin should ideally be above 7 g/dl, INR <1.5, platelet count above 50,000/cumm, and fibrinogen levels maintained at least 100 mg/dl, preferably above 150 mg/dl. Correcting pH to ≥7.2 before administration is also advised as efficacy diminishes below pH 7.1.[48]

Since its first reported use in obstetric hemorrhage by Moscardo et al numerous case reports and series have documented successful outcomes with rFVIIa. Despite its benefits, the high cost and the need for venous access limit its widespread use. Current guidelines often reserve rFVIIa for late-stage, severe PPH cases or as a last resort before or after hysterectomy.[49]

Tranexamic acid

Tranexamic acid is a synthetic analogue of lysine that inhibits fibrinolysis by reducing the binding of plasminogen and tissue plasminogen activator to fibrin. The WHO recommends TXA administration as soon as increased bleeding is observed within the first 3 hours post-delivery, given intravenously at a dose of 1 gram regardless of the mode of delivery. If bleeding persists after 30 minutes or resumes within 24 hours of the first dose, a second 1-gram dose may be administered. TXA's antifibrinolytic effect lasts approximately 7-8 hours in the serum, and its concentration in breast milk is minimal, unlikely to affect infants.[50]

NICE guidelines (2023) advocate TXA use for all women having PPH. The WOMAN trial demonstrated that early TXA administration within 3 hours of delivery caused 20%-30% reductionin bleeding-related deaths without increased adverse effects, and a 36% decrease in the incidenceof surgical interventions.[51] TXA is an effective intervention for managing bleeding in postpartum women, irrespective of the cause. Recent evidence supports TXA's use both preventively and therapeutically for PPH, with minimal risk of thromboembolic complications.

DDAVP

DDAVP is a synthetic analogue of L-arginine vasopressin, the antidiuretic hormone, with hemostatic properties. It increases plasma levels of Factor VIII and von Willebrand Factor in both healthy individuals and those with deficiencies. Acting primarily on V2 receptors, desmopressin promotes the release of cyclic adenosine monophosphate, stimulating the secretion of vWF and tissue plasminogen activator from vascular endothelial cells and platelets. Unlike plasma-derived products, desmopressin carries no risk of infection. It is indicated for von Willebrand disease, hemophilia A, or congenital

platelet disorders to manage bleeding episodes, particularly refractoryPPH. [52]

DDAVP infusion increases FVIII and vWF levels by two- to six-fold, with individual responses varying. The typical therapeutic dose is 0.3 to 0.4 µg/kg administered intravenously over 30 minutes, achieving peak plasma levels within 30 to 90 minutes. Intravenous administration has a quicker onset compared to subcutaneous or intranasal formulations, which reach peak efficacy in 60 to 120 minutes.[53] Repeat doses every 12 to 24 hours generally result in a gradual reductionof the initial FVIII increase observed with the first dose, though the initial response can be reproduced if administrations are spaced two to three days apart.

Common adverse effects include flushing, headaches, and compensatory tachycardia, whilehyponatremia is the most serious reported adverse effect. Desmopressin has no known antidote, and absolute contraindications include hypersensitivity to DDAVP.

Permissive resuscitation

Hypotensive resuscitation involves deliberately limiting fluids during early hemorrhagic shock to maintain lower-than-normal blood pressure, sustaining organ perfusion until bleeding is controlled. It serves temporarily until definitive hemorrhage control or surgery can be performed. Normal hemodynamic parameters should be restored when blood products and improved hemorrhage control measures are available.

Permissive hypotension permits minimal peripheral vasodilation to maintain adequate organ perfusion and reduce the risk of multiorgan failure. Administering small volumes of crystalloids reduces the risk of dilutional coagulopathy, and maintaining lower blood pressure helps preserve pre-formed blood clots. In contrast, aggressive fluid resuscitation can worsen coagulopathy and bleeding by increasing intravascular pressures, diluting clotting factors, and inducing hypothermia, leading to patient deterioration. Excessive elevation of blood pressure can also increase red blood cell loss, exacerbating tissue hypoxia and acidosis.[54]

A cohort study of women with PPH found that those receiving lesser fluids showed fewer signs ofshock and required fewer blood products. Additionally, their lab results revealed lower levels of fibrinogen, hemoglobin, hematocrit, platelets, prolonged prothrombin time, and partial thromboplastin time.[55] Administration of more than 4 liters of fluids was associated with increased subsequent bleeding and adverse maternal outcomes. This approach may exacerbate preexisting cardiovascular conditions and fluid balance disorders such as syndrome of inappropriate antidiuretic hormone secretion and diabetes insipidus. Recent clinical guidelines recommend permissive hypotension and controlled resuscitation to maintain organ perfusion without worsening bleeding, which can occur with aggressive fluid administration.

Acute normovolemic hemodilution

It can be used in high-risk cases like placenta accreta where significant blood loss is anticipated during surgery. It involves rapid and precise withdrawing of the patient's whole blood just before surgery. The surgery is subsequently conducted in hemodiluted state, leading to a reduced loss ofred blood cells. Following surgery, the blood is reintroduced into the patient, enabling the maintenance of sufficient hematocrit levels without requiring extra transfusions. It minimizes the need for allogenic transfusions and associated complications. ANH in pregnant women has not been thoroughly studied and till date has been used in patients with abnormal placentation only.[56]

CONCLUSION

Refractory PPH contributes significantly to maternal mortality and morbidity, much of which is preventable through timely and appropriate interventions. MLM aid in early prediction and enhance PPH recognition. The E-motive approach and ABL estimation facilitate early detection and swift treatment of PPH. Simulation training exercises such as PPH Drills prepare healthcare teams to manage emergencies effectively. UBT and NIUPSD represent breakthrough in conservative management. The NASG assists in shock management and during patient transport. Viscoelastic testing- guided, goal-directed hemostatic treatment should be adopted where feasible. For cases showing evidence of fibrinogen deficiency, initial treatment with cryoprecipitate or fibrinogen concentrate is preferred over fresh frozen plasma. Standardized algorithms for managing massive hemorrhageprotocols are crucial developments.

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