Planning for hemorrhage

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Article outline

Although maternal hemorrhage is a leading cause of maternal mortality world-wide [1,2], the mortality rate directly associated with major hemorrhage in developed countries is low (eg, 3.3 deaths/million maternities in the United Kingdom) [3]. Maternal morbidity may provide a more sensitive marker of outcome. In one study, the rate of severe obstetric morbidity was 12 per 1000 deliveries, and severe hemorrhage constituted more than half of this by the authors' definitions [4]. Morbidity may derive from transfusion of any blood or blood products, the effects of massive transfusion per se, or from pharmacologic, surgical, or radiologic treatment of the cause of hemorrhage.

Significant hemorrhage can be defined broadly as sufficient bleeding to expose the mother to potential morbidity, including that from transfusion of blood products. Quoted rates of blood transfusion in obstetric practice vary from 1.3% to 2.6% [5,6]. In recent years, greater appreciation of the risks and costs of transfusion has led to successful attempts to reduce such practice by using guidelines and education [7].

This article outlines the techniques that may be used to limit and more effectively treat hemorrhage, with particular attention paid to reducing the use of allogeneic blood transfusion. Some measures require consideration many weeks before delivery, so it is necessary to predict those women at risk for significant hemorrhage. Consultation allows overall assessment of any additional anesthetic risk factors, advice and counseling of the parturient, and planning and coordination with the obstetric team for any antenatal measures required [8]. Optimal care of major hemorrhage patients is reviewed elsewhere [9,10].

Risks of blood transfusion

Risk of infection from allogeneic blood is currently less because of the increased screening of donors, increased testing for viral components and antibodies, and, in some countries, routine leukodepletion. Further reductions are likely in the future [11,12]. Transmission rates are low enough that mathematical models are used to estimate risk and there is some uncertainty about true rates [13]. Some risks and estimated incidences for blood transfusion are summarized in Table 1[14].

Table 1. Risks of blood transfusion and estimated incidences

Risk	Incidence (per unit of blood)
Acute hemolytic reaction	1:25,000
Fatal acute hemolytic reaction	1:600,000
Delayed hemolytic reaction	1:2,500 – 1:6,000
Febrile, nonhemolytic reaction	1:100
Allergy	1:100 – 1:300
Anaphylaxis	1:20,000 – 1:50,000
Transfusion-related acute lung injury	Unknown; rare
Viral infections	
HIV	1:913,000
Hepatitis B virus	1:63,000 – 1:200,000
Hepatitis C virus	1:250,000 – 1:500,000
Prion infections	
Creutzfeldt Jacob Disease, variant Creutzfeldt Jacob Disease	Theoretical risk only
Bacterial infections	
Fatal sepsis (eg, yersinia enterocolitica)	< 1:1 million
Parasitic infections	
Malaria	1:400,000 – 1:4 million

Adapted from Physician's guide 2001. Informed consent for blood and blood products. In: Pi D, Wadsworth L. editors. Appendix A. British Columbia Provincial Blood Coordinating Office; Vancouver, B.C; 2001; p. 49 – 50.

Autologous blood transfusion can eliminate many of these infective risks. Administrative error still may lead to hemolytic reactions and death, however, and stored autologous blood may be contaminated by bacteria. Often the need for a massive transfusion exceeds available autologous stores, which exposes the patient to further risks, including coagulopathy, hypothermia, hypocalcemia, and hyperkalemia.

Etiology of hemorrhage and prediction of the high-risk parturient

Frequently the cause of obstetric hemorrhage involves multiple factors that can be divided broadly into five main groups (Table 2).

Table 2. Etiology of obstetric hemorrhage and some associated obstetric risk factors

Etiology group	Examples of risk factors
Placental abnormalities	
Congenital	Bicornuate uterus
Location	Placenta previa

Attachment/invasion	Placenta accreta/increta/percreta
Acquired structural	Leiomyoma, previous surgery
Peripartum	Uterine inversion, uterine rupture, placental abruption
Coagulation disorders	
Congenital	Von Willebrand's disease
Acquired	DIC, dilutional coagulopathy, heparin
Lacerations and trauma	
Planned	Cesarean section, episiotomy
Unplanned	Vaginal/cervical tear, surgical trauma
Uterine atony	Multiple gestation, high parity, prolonged labor, chorioamnionitis, augmented labor, tocolytic agents
Retained uterine contents	Products of conception, blood clots

Antenatal assessment

The existence of some of the obstetric risk factors may be known early in pregnancy from history and examination. Investigations may identify further patients at risk of hemorrhage and may need to be repeated serially during the pregnancy. Table 3 summarizes some useful antenatal investigations.

Table 3. Antenatal investigations and associated conditions

Investigation	Associated conditions
Full blood count (including Hb, platelets)	Anemia, thrombocytopenia
Clotting screen (including fibrinogen, -dimers)	Anticoagulants, DIC, dilutional coagulopathy
Abdominal ultrasound	Placenta previa/accreta
MRI	Placenta accreta/increta/percreta
Others (eg, calcium [ionized], liver enzymes)	Massive tranfusion hypocalcemia HELLP

Detection of anemia more than physiologic anemia of pregnancy is important, because anemia at delivery increases the likelihood of a woman requiring blood transfusion. Iron studies may demonstrate deficiency. Coagulation studies may be required in the presence of congenital or acquired coagulation defects. A case report of two cases of placenta accreta with myometrial invasion (increta and percreta) suggests that elevated creatine kinase may be a marker of invasion in cases of probable abnormal adherence of the placenta [15]. In such cases, however, imaging plays the major role.

Imaging investigations are useful in the detection of placental abnormalities, with placenta previa and placenta accreta the most important identifiable risk factors for massive hemorrhage. Ultrasound studies identify placental location, and their ability to detect placenta accreta has been well examined and reviewed [16]. Conventional gray-scale assessment has a sensitivity of 93%, a specificity of 79%,

and a positive predictive value of 78% in the diagnosis of placenta accreta when previa and previous cesarean scar are present [17]. Certain characteristics, such as the ”Swiss cheese appearance” with placenta previa, are associated with a threefold increase in mean blood loss during cesarean section [18]. Color Doppler may increase the specificity to 96%, which gives a positive predictive value in high-risk patients of 87% and a negative predictive value of 95% [19] and allows better assessment of the depth of myometrial or serosal invasion [18]. Further imaging by MRI is recommended to assess bladder involvement in percreta and assess high-risk cases with posterior placental location [20].

Antenatal optimization of parturient

Antenatally the patient's condition should be made optimal, and the following medications may be considered alone or as an adjunct to autologous predonation of blood.

Medications

Iron supplementation prevents and treats iron deficiency anemia. Iron is particularly valuable when erythropoiesis is stimulated by autologous blood predonation or erythropoietin. Intravenous iron therapy may be more effective than oral therapy but carries the risk of severe anaphylactoid reaction [21]. Folate supplementation prevents megaloblastic anemia in most parturients. A recent systematic review concluded that routine iron and folate supplementation prevents anemia; however, to date, studies have not shown a substantive effect on maternal or fetal outcome [22].

The use of recombinant human erythropoietin (rHuEPO), beyond the established efficacy in treating anemia in patients with renal failure, is increasing [23]. During normal pregnancy there is a twofold to fourfold increase in maternal erythropoietin levels [24,25]. In parturients with renal failure [26] or functioning renal transplants [27], rHuEPO is beneficial. To prevent anemia in pregnant renal failure patients, a higher dose of rHuEPO may be required [28].

The dose of rHuEPO for parturients without renal disease has varied widely. The first use in pregnancy, in the absence of renal disease, was for a patient with low serum erythropoietin levels and hypoproliferative bone marrow [29]. rHuEPO has been used to speed recovery from postpartum anemia [30]. In a recent report, 19 of 26 pregnant women with iron deficiency anemia (Hb< 8.5 g/dL) who were resistant to oral iron supplementation had a normal hemoglobin level 2 weeks after starting treatment with parenteral iron and rHuEPO [31]. No reason was found for the lack of response or worsening of anemia in the remaining 7 women. Finally, rHuEPO is used in association with autologous predonation to increase the number

of units collected and to prevent preoperative anemia [32]. More work is needed to elucidate the most appropriate dosing regimen for erythropoietin (and iron supplementation) and to clarify further the side-effect profile of the drug [33].

There is conflicting evidence in animals regarding whether rHuEPO crosses the placenta [34,35]. In humans, placental transfer does not seem to occur [36], and fetal effects, such as polycythemia, have not been seen in clinical use [37]. Hypertension, an established side effect in renal patients, is not a major problem in pregnancy [31]. Further experience is necessary because this side effect mistakenly might be ascribed to preeclampsia or eclampsia [37]. Theoretical concern over increasing thrombotic risk may limit treatment to aim for normal hemoglobin levels only.

A novel erythropoiesis-stimulating protein has been studied in nonpregnant patients [38]. This protein is a biochemically distinct, genetically engineered molecule with prolonged serum half-life and in vivo biologic activity. It may be more efficacious than erythropoietin, with more convenient once-weekly dosing [39]. Currently it does not have Food and Drug Administration approval.

Any infection, such as chorioamnionitis, is associated with increased blood loss at cesarean section and risk of disseminated intravascular coagulopathy [40]. Infection should be treated aggressively with appropriate antibiotics.

Preoperative autologous donation

Strategies used to reduce allogeneic transfusion by collection of autologous blood include preoperative autologous donation (PAD), acute normovolemic hemodilution (ANH), and intraoperative blood salvage (IBS) [41]. Of these, only PAD requires early implementation.

Preoperative autologous donation is limited by the maximum lifespan of stored blood, so collection can start 6 weeks before planned delivery. One unit is collected per week, although this interval may be reduced to every 3 days if needed and if anemia does not develop. At the authors' hospital, the hemoglobin threshold for first donation is 10.5 g/dL and 10 g/dL for the second unit onward. Contraindications include some viral infections (HIV, hepatitis C) and concurrent bacteremia. Iron supplementation is routine, and some programs use erythropoietin to boost yield. A recent review of PAD studies in nonpregnant patients showed an increased yield of red blood cells with exogenous erythropoietin therapy [42], although responses in third trimester pregnancy may differ from those seen in the study patients. Risks associated with transfusion of

autologous units include incompatibility reactions from administrative error and bacterial contamination. An argument has been made for more liberal transfusion triggers if autologous blood is available [43]. Predelivery anemia is an important risk factor for transfusion, so as much time as possible is left between the last donation and delivery (preferably 5–10 days) [44].

Autologous techniques are used increasingly for all kinds of surgery. In contrast to ANH and IBS, PAD has been applied widely to the obstetric population at high risk for hemorrhage (eg, placenta previa, elective cesarean hysterectomy) and when the patient has antibodies to high-frequency antigens. With the number of parturients who have undergone this procedure, it is reasonable to suggest that PAD is a safe procedure for mother and fetus. The only clear side effect is maternal vasovagal reaction (2%) [44]. The maternal hemodynamic effects from donating 450 mL of blood are less than orthostatic stress, and fetal umbilical systolic/diastolic ratio is not significantly affected [45]. Because the overall cost of PAD is considerable, the indications continue to be debated [46,47]. Some authors recommend the procedure when the risk of transfusion is 10% [48], others when risk is 50% [49].

Immediately before delivery

Coagulation correction

Predelivery treatment of known coagulation defects may be required. Examples include the use of desmopressin acetate (DDAVP) in von Willebrand's disease type I [50], hemophilia carriers with low factor VIII levels [51], and other specific factor treatment in which deficiency exists. Pregnant women with procoagulant conditions often are treated with nonsteroidal antiinflammatory drugs, including aspirin, oral anticoagulants such as warfarin, or more commonly, unfractionated or low molecular weight heparin [52]. Hemorrhage risk may be reduced by either stopping or reducing therapy or by switching therapy to unfractionated heparin, which provides more measurable and reversible anticoagulation.

Acute normovolemic hemodilution

Acute normovolemic hemodilution involves the collection of autologous blood immediately before surgery or delivery with concurrent fluid infusion to maintain normovolemia. Red cell mass lost during ensuing blood loss is reduced as a result of the reduced hematocrit of the blood. The collected autologous blood can be reinfused as needed.

A few randomized controlled clinical trials have compared the efficacy and cost of ANH with that of PAD for surgical procedures in cardiology, orthopedics, and urology with high-risk for transfusion. ANH is cheaper than PAD, and a recent metaanalysis suggests comparable efficacy at reducing allogeneic transfusion [53]. Case study and multiple mathematical model analysis found that ANH is most effective in preventing allogeneic transfusion when (1) the patient's initial hematocrit is high, (2) aggressive dilution to low hematocrits below 0.28 or even 0.20 is performed, and (3) blood loss is more than 2 L or 50% of blood volume [54–56].

Concerns about possible fetal effects of inducing acute maternal anemia led to a delay in studying this technique in obstetric practice. There were no adverse fetal or maternal effects from ANH among 38 parturients (33 with placenta previa) who underwent cesarean section with high risk of hemorrhage [57]. Parturients had a mean mass of 967 g of blood collected, and their circulating blood was diluted to a mean hematocrit of 0.25 before surgery. Immediately before retransfusion, which commenced at the anesthesiologist's discretion intraoperatively or postoperatively, the mean hematocrit was 0.22 (range, 0.18–0.27). In one parturient with 5-L blood loss, transfusion of 2 U of PAD and 2 U of ANH-collected autologous blood led to a 24-hour postoperative hemoglobin of 8.3 g/dL compared to 10 g/dL preoperatively [57]. A Jehovah's Witness parturient who underwent cesarean hysterectomy for placenta percreta had uncomplicated ANH [58].

It is premature to suggest that fetal and maternal safety have been established. Compared to PAD, however, ANH reduces the risk of administrative incompatibility error and bacterial contamination and allows infusion of fresh whole blood with full coagulation function [57]. In some centers, carriers of certain viruses are not allowed to donate autologous blood and, for these patients, ANH remains an option.

At time of delivery

When major hemorrhage is anticipated, a plan is necessary and multidisciplinary discussion facilitates this process. Consultation with the radiology, urology, vascular surgery, hematology, and anesthesia disciplines ensures the best possible care for the parturient. Planning for delivery must address the following concerns.

Anesthesia planning

General or regional anesthesia

Regional anesthesia for cesarean section or examination under anesthesia of the bleeding parturient may be contraindicated by hypovolemia or coagulopathy. For planned cesarean section without such contraindications, some retrospective studies suggest that general anesthesia with a volatile agent is associated with greater blood loss than regional techniques [40,59,60], although some others disagree [61]. A retrospective analysis of 514 parturients with placenta previa who underwent cesarean section identified general anesthesia as a risk factor for greater blood loss and a need for transfusion [59]. There was no difference in the incidence of intraoperative or anesthetic complications, and regional anesthesia was found to be a safe alternative to general anesthesia. Using regression analysis of data collected during a review of 350 cases of placenta previa, regional anesthesia was associated with a significantly reduced estimated blood loss and need for transfusion [60].

A UK survey suggested that anesthesiologists with obstetric experience are more likely to use a regional technique for placenta previa than anesthesiologists who practice less obstetric anesthesia [62]. In another survey, the percentage of anesthesiologists who would choose a regional technique dropped from 95% to 49% when comparing a case of stable elective placenta previa with a laboring and hemorrhaging placenta previa case [63].

Equipment

Other issues relevant to planning and expediting the anesthetic management of the potentially hemorrhaging parturient include (1) preparing adequate transfusion apparatus: adequate large-bore intravenous access, fluid warmer, rapid infuser, warming mattress, warm air blanket, and staff to porter blood work and blood products and assist with fluid therapy; (2) providing appropriate monitoring: arterial line for beat-to-beat blood pressure and frequent blood sampling, central venous line, and urometer to monitor renal function and adequacy of perfusion; and (3) preparing the appropriate site: the at-risk parturient should deliver where there are adequate facilities and staff with sufficient expertise in management of massive hemorrhage.

Intraoperative blood salvage

Cell saver equipment is used for the intraoperative salvage of shed red blood cells, which are then washed, suspended in saline, and infused back into the patient at a rate up to the equivalent of 12 U of banked blood per hour [64]. The technique of

IBS requires some experience but becomes cost effective after recovery of the equivalent of 2 to 3 U. In a survey of techniques to reduce allogeneic transfusion in the United States, IBS was used in 82% of responding centers but less in smaller hospitals, public hospitals, and those without open-heart surgery facilities [65]. Maternal death caused by hemorrhage does occur in smaller hospitals, however, and such hospitals are less likely to have IBS facilities available. The possible impact of IBS on maternal mortality has been questioned, regardless of any specific safety concerns [66]. Safety concerns are based on cases of disseminated intravasular coagulopathy (DIC), cardiovascular collapse, and death from amniotic fluid embolism syndrome. The exact mechanism of amniotic fluid embolism syndrome is currently unclear and some suggest renaming it ”anaphylactoid syndrome of pregnancy” [67] or “sudden obstetric collapse syndrome” [68].

Despite such concerns, several clinical series and case reports (totaling 178 patients) of IBS use during cesarean section have been published [69–74]. There was one case of heparin overdose [74] and one death in a Jehovah's Witness patient. In the latter case, hypoxia and ensuing cardiac arrest occurred 10 minutes after starting transfusion of salvaged blood at the end of the cesarean section [71]. A clinical diagnosis of amniotic fluid embolism syndrome was made.

Laboratory investigations have studied the efficiency of clearance of amniotic fluid components, including fetal squamous cells [75,76], alpha-fetoprotein [75], tissue factor [77], fetal blood cells/hemoglobin [75,76], trophoblastic tissue [75], and bacteria [76]. These studies suggest effective clearance of solute proteins but incomplete clearance of cellular components, such as fetal squames or red cells, despite the use of leukodepleting filters. Endothelin-1 may play a role in the development of amniotic fluid embolism syndrome [78]. Although this has not been tested, it is a tissue factor and so may be cleared by the cell salvage procedures [79].

Other potential side effects and risks are associated with IBS. Hypocalcemia and hypomagnesemia may occur. Because saline is used to wash and suspend the cells, metabolic acidosis from the chloride load may occur. This occurrence may be prevented by using a balanced solution [80]. A series of four cases of fatal air embolism, associated with infusion of recovered blood under pressure, has been reported [81]. The authors estimated that the frequency of this complication was 1 in every 30,000 cases using IBS. Avoiding pressure transfusion when possible and air venting have been emphasized. Alloimmunization to fetal antigens absent on maternal erythrocytes may occur [79], including the Rhesus D antigen for which anti-D immunoglobulin may be given [75].

Establishing the safety of IBS in obstetrics is problematic and requires large numbers of patients in controlled trials. Some researchers suggest that embolism

of some amniotic fluid into the maternal circulation is common but that the disastrous clinical syndrome is rare (0.01%–0.001%). As a result, demonstration of safety of IBS is an even greater challenge. For the moment, the only clear indication for cell salvage in obstetrics is when it is the only way to augment the patient's oxygen-carrying capacity to preserve function or life, such as a severely hemorrhaging and anemic Jehovah's Witness parturient [79].

Surgical planning

When major hemorrhage is anticipated at cesarean section, a surgical plan is necessary. Placement of femoral artery cannulae with infrarenal aortic or bilateral internal iliac balloons allows intraoperative balloon inflation to help control major hemorrhage [82,83]. The cannulae also can be used as access for later embolization. A urologist may place ureteric stents preoperatively to reduce the risk of urologic injury if hysterectomy is planned or required [16], and the urologist is invaluable if the placenta invades the bladder. A vascular or specialist gynecologic oncologic surgeon may be needed if hypogastric artery ligation or aortic dissection is required [16]. Ligatures may be placed around the vessels after dissection before hysterotomy so that they may be tied off if needed.

Blood loss in uncomplicated cesarean section is reduced if the placenta is allowed to separate and deliver spontaneously rather than be removed manually by the obstetrician [84,85]. Allowing spontaneous placental separation provides maximal decrease in implantation bed surface area and spiral artery perfusion pressure. If there is abnormal adherence, alternative strategies might be considered without necessarily initiating placental separation and major hemorrhage. One example is proceeding directly to hysterectomy with the placenta in situ. Successful conservative management of placenta percreta (placenta left in situ and the woman treated with methotrexate) has been described [86].

Intraoperative management

Oxytocics

Because uterine hypotonia leads to hemorrhage, prophylactic or early administration of oxytocics assists in minimizing blood loss. A range of uterotonic drugs is given to treat hypotonia, often using a second or third agent if hypotonia persists.

Oxytocin may be given by infusion or intravenous (5 U) bolus. A recent report cautions against the use of larger boluses because cardiac arrest occurred in a parturient with high spinal block and hypovolemia, possibly after the marked vasodilatation seen with bolus oxytocin administration [3]. Ergonovine and methylergonovine may be given by intramuscular or slow intravenous injection [87]. Their marked cardiovascular side effects are caused by vasoconstriction, which leads to hypertension and coronary vasospasm. Bronchospasm also has been reported, so use of ergonovine in patients with asthma is not recommended.

The 15-methyl analogue of prostaglandin F2alpha (Hemabate) may be given by intramuscular or intramyometrial injection and may cause bronchospasm. Prophylactic oral or rectal misprostol reduces mean blood loss at delivery, although a role in treatment of hemorrhage has not yet been established [88].

Maintenance of intravascular homeostasis

Intravascular volume

Continued maintenance of intravascular volume and normotension with crystalloid and colloid solutions provides optimal tissue perfusion. Maintaining normovolemia makes a small contribution to minimizing red cell and coagulation factor loss. The dilution of blood components during hemorrhage follows an exponential curve when normovolemia is maintained with other fluids [89], such that they are diluted to 37% after one blood volume is lost. Step-wise dilutions without constant normovolemia lead to a slightly greater dilution effect for the same volume of blood lost.

Hematocrit and hemoglobin: transfusion trigger

A major reason for the decrease in blood transfusion in recent years is a marked change in the threshold of hemoglobin concentration at which clinicians administer blood [90]. Guidelines suggest that specific thresholds of hemoglobin concentration should not be applied rigidly. Instead, transfusion should be based on physiologic signs of inadequate oxygenation. A healthy patient usually does not need intraoperative transfusion until the hemoglobin concentration is below 6 g/dL [91]. In healthy patients, there is no evidence that acute, severe, isovolemic anemia to 5 g/dL leads to inadequate systemic oxygen delivery [92].

Guidelines recognize the potential for continued major hemorrhage as a trigger for transfusion [93]. Evidence from critical care studies suggests that morbidity is not increased by dropping the transfusion threshold to 7 to 9 g/dL from 10 to 12 g/dL [94]. A retrospective study found factors leading to transfusion in cesarean section patients and compared 103 transfused patients with an apparently matched group for these factors (24 patients who were not transfused) [95]. Average hematocrits for the groups were 0.28 and 0.23, respectively, but no differences in postoperative morbidity, including wound complications, infection rates, and time to discharge, were found.

Coagulation

Coagulation factors dilute to 37% of prehemorrhage levels after surgical loss of one whole blood volume with isovolemic factor-free replacement [89]. This level approaches the critical 30% level whereby dilutional coagulopathy may occur. Except for cases of pathologic coagulopathy that result from another cause, such as DIC or hemolysis, elevated liver enzymes, and low platelets, loss of one whole blood volume is an appropriate time to consider factor replacement using fresh frozen plasma. Cryoprecipitate and fibrinogen may be required, and close liaison with a hematologist and the laboratory and blood bank is helpful.

Drugs used in other settings in which major blood loss is common (liver transplantation and cardiac surgery) include aprotinin and tranexamic acid. Tranexamic acid was used successfully in a patient who hemorrhaged after cesarean section with placenta accreta [96], but there was no evidence of coagulopathy when the drug was given. There is no further evidence for its use in obstetrics currently. Use of these drugs should follow consultation with a hematologist when other measures to control coagulopathy and hemorrhage have failed.

Platelet counts do not fall as rapidly as a dilution curve would predict [97], probably because of continuing release from the spleen. The minimum recommended platelet count before major surgery is between 50 and 100 Å~ 109/L depending on the risk of bleeding [91]. Platelet transfusion is reasonable when there is evidence of abnormal microvascular bleeding and platelet count is below 100 Å~ 109/L.

Other considerations

Maintenance of normothermia helps prevent coagulopathy, metabolic acidosis, and even ventricular fibrillation. Because obstetric hemorrhage can occur unexpectedly

and rapidly, certain measures may be needed to limit acute torrential hemorrhage, thereby allowing time for resuscitation and treatment or transfer to a site where definitive treatment may be expedited.

The technique of applying external aortic compression to compress or occlude the abdominal aorta and reduce uterine and pelvic arterial flow and increase proximal aortic pressure was described many years ago [98]. A fist is pressed firmly into the abdomen in the midline just above the umbilicus, with the palmar aspect of the hand directed caudad. In one case report, this measure had a dramatic effect on continuing hemorrhage and allowed time for resuscitation and surgical control [99]. The technique was assessed in 20 normovolemic nonbleeding postpartum patients who were all able to tolerate it for 90 seconds [100]. Two patients had reduced and 11 patients had absent lower limb blood pressure during compression from obliteration of the femoral pulse. Reasons for failure in 7 patients were not identified, but it is possible that an effect may have been measurable in some patients if hypovolemia were present. In postpartum patients, external compression is potentially useful. Internal aortic compression by the surgeon using a hand or clamp is another possibility that may be considered during an emergency operative procedure.

The use of military anti-shock trousers in hemorrhagic shock is well documented [101], and these trousers have been used to arrest major hemorrhage temporarily followed by transcatheter arterial embolization in two postpartum patients [102]. Inflation to 25 to 35 mm Hg is usually sufficient and stops venous and even arterial bleeding [102].

Other temporizing surgical measures include bimanual uterine compression, vaginal and uterine packing with gauze [103] or gauze within a plastic drape [104], or balloon devices in the cervical canal, including a Foley urinary catheter [105], Sengstaken-Blakemore tube [106], or a specifically designed tamponade balloon [107]. When bleeding is caused by coagulopathy, such measures may be sufficient once the coagulopathy is corrected.

Further treatment after stabilization

Once hemorrhage has been controlled, the anesthesiologist must consult with the obstetrician and others regarding further care. Patients who have received massive transfusion are best managed in a high-dependency or intensive care unit for close monitoring for complications. Removal of packs may involve risk of further hemorrhage, necessitating appropriate planning.

Some potential complications of massive transfusion include polycythemia, hyperviscosity syndromes or pulmonary edema from overtransfusion, airway

changes and compromise [108], renal failure, and acute respiratory distress syndrome from transfusion-related acute lung injury or other cause. Pulmonary embolism is also a risk, and once hemostasis is assured and coagulation normalized, prophylaxis with subcutaneous heparin should be given. Rarely, hypopituitarism (Sheehan's syndrome) may occur in parturients who have experienced prolonged periods of hypotension.

Future alternatives to blood transfusion

In the past few years, considerable research has been conducted regarding oxygen-carrying substitute fluids, with some undergoing phase III clinical trials [109,110]. There are two classes of red blood cell substitutes: hemoglobin-containing fluids and perfluoro compound emulsions [111].

Problems with hemoglobin-based fluids include high oxygen affinity, short plasma half-life, auto-oxidation, and potential for vascular reactivity, probably by binding nitric oxide. Unless bovine hemoglobin proves useable, an adequate supply of human hemoglobin will be a problem because recombinant DNA technology-based production would be expensive.

The perfluoro compounds are water insoluble and the emulsions are viscous. Dissolved oxygen also is linearly related to partial pressure, so high inspired oxygen concentrations are needed. Polyfluoro-octobromide (Perflubron) is the most promising of this class because it is less viscous and has the highest oxygen-carrying capacity. Trials in intraoperative hemodilution are taking place. More studies are needed before safety and efficacy of these substitutes for blood transfusion can be demonstrated.

Audit and review

Finally, audit of cases of significant hemorrhage and practice simulations of major obstetric hemorrhage have been recommended [3] and may allow anesthesiologists and other members of the care team to identify areas in which care may be improved. Use of some of these measures may limit hemorrhage and allogeneic transfusion in particular, with the goal of decreasing maternal morbidity and mortality. Table 4 summarizes the antenatal and perinatal approaches outlined in this article.

Table 4. Summary of approaches to limit allogeneic and autologous blood transfusion and treat obstetric hemorrhage

Timing	Considerations
Antenatal / before delivery	
Medications	Iron
	Folate

Erythropoietin
Antibiotics
Measures Preoperative autologous donation
Correction of coagulopathy
Acute normovolemic hemodilution
Around time of delivery
Anesthesia planning Regional vs general anesthesia
Equipment (infusers, warmers, staff, site)
Intraoperative blood salvage
Surgical planning Specialist staff (radiology, urology, oncology)
Spontaneous vs manual placental delivery
Intraoperative
Oxytocics Oxytocin, ergonovine, 15-methyl-PGF2Éø
Maintenance of intravascular homeostasis Volume by crystalloids/colloids
Hematocrit by blood transfusion ?trigger
Coagulation by fresh frozen plasma, cryo, platelets
Others Maintenance of normothermia
Temporiszng measures
Aortic compression (internal or external)
Military antishock trousers

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