The Role of the Anesthesiologist in Management of Obstetric Hemorrhage

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Hemorrhage after childbirth, whether the delivery is vaginal or operative, is a clinical situation where knowledge, communication, and the availability and utilization of resources all play prominent roles. In this article we describe the thought processes and decisions that should occur, and the actions that should be taken by the anesthesiologist in the face of suspected, expected, or unexpected hemorrhage in the labor and delivery suite. Semin Perinatol 33:116-123 © 2009 Elsevier Inc. All rights reserved.

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“When determining a course of action, it often helps to know what you’re up against.”

Henry Kissinger

In a major hospital in the largest city in the Western world, a woman is dying of postpartum hemorrhage. Her obstetrician summons expert help, who establishes venous access, obtains blood, and directs transfusion therapy while the obstetrician continues his effort to stop the bleeding. In many ways, it appears we are observing a modern day obstetric anesthesiologist in action. However, anesthesia is yet to be discovered. The year is 1825. The helper is James Blundell, an obstetrician and physiologist at Guy’s Hospital in London, who, next to James Young Simpson perhaps, should be regarded as the other forefather of obstetric anesthesia.1

Although times have undoubtedly changed, and much for the better in the area of obstetric hemorrhage, the principles remain the same. Hemorrhage is a life-threatening emergency. Teamwork is essential, multiple tasks need to be accomplished quickly and with expertise, and the role of the obstetric anesthesiologist is to maintain vital functions, replace lost blood, and provide the conditions under which hemorrhage can be controlled. In this article, we will discuss the role of the anesthesiologist in managing obstetric hemorrhage, both anticipated and unexpected.

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Unscheduled Obstetric Hemorrhage

The clinical scenario we are discussing in this section is when the anesthesiologist is called to see and assume care for a patient with an unexpectedly high blood loss after a vaginal delivery. The approach and issues are similar when the bleeding occurs during an expected routine cesarean delivery, but during a cesarean delivery, the anesthesiologist is already present, usually more prepared and certainly more familiar with the patient. It is our experience that more confusion, misinterpretation, and miscommunication occurs in the case of unexpected postpartum hemorrhage outside of the operating room.

Arrival and Initial Assessment

Upon arrival, the anesthesiologist should expeditiously review the medical, obstetric, and anesthetic history and examine the patient with a focus on blood pressure, oxygen saturation and heart rate, capillary refill, and the temperature of the extremities (Table 1). Assessing core temperature at this time is useful as hypothermia may compromise coagulation status, although usually not until the temperature is 34°C or lower. Most importantly, at first contact, hemodynamic status should be correlated to estimated blood loss, and discrepancies should be communicated to the obstetrician. A brief examination of the airway is mandatory; the airway in the obstetric patient may change during labor, and anticipated airway problems should be communicated to the obstetrician. A brief examination of the airway is mandatory; the airway in the obstetric patient may change during labor, and anticipated airway problems should be communicated to the obstetrician without delay, because the need for general anesthesia for hemorrhage is unpredictable but omnipresent. Adequacy of analgesia should also be addressed. Obstetric efforts to control the hemorrhage are often painful, and adequate pain
control will allow better exposure and access to the bleeding site. The use of an indwelling epidural catheter for analgesia for surgical control of minor to moderate hemorrhage is almost always preferable to general anesthesia, but consideration of transfer to the operating room for better exposure and to allow for the possible need for general anesthesia should be considered from the very start of hemorrhage management. If pain control cannot be achieved in the labor room, then transfer to the operating room should be initiated to provide appropriate neuraxial or general anesthesia, or occasionally intravenous sedation/analgesia, because attempted surgical management of all but the most trivial bleeding in the absence of adequate analgesia/anesthesia is a recipe for chaos, failure, and potential disaster.

It does happen that the anesthesiologist arrives at the scene, is told that the patient has lost 800 mL of blood, and finds the heart rate is 138, blood pressure is 80/40 mm Hg, and the patient is only semi-conscious. Clearly, a new assessment of blood loss is needed at that point. The anesthesiologist should quickly review ongoing fluid resuscitation and pharmacotherapy and assume responsibility for these. Place arterial line early if significant hemorrhage present or anticipated. Send initial lab sample (hemoglobin, coagulation status) if not already sent. Order blood and blood products as needed
calcium levels in the face of rapid transfusion. In the absence of arterial access, repeated venipunctures will jeopardize needed future venous access sites.

Team Approach, Communication, and Goals of Therapy
The extent of bleeding is almost always underestimated in obstetric patients. All obstetric hemorrhage should be considered as severe until proven otherwise. The contrary can only be presumed once the hemorrhage is controlled, the blood loss quantified (or at least estimated), and the patient remains hemodynamically stable throughout the bleeding episode and afterward, with maintenance of adequate urine output. All bleeding obstetric patients should be considered under-resuscitated until sustained hemodynamic stability is documented. Blood loss should be estimated at the first encounter with the patient followed by regular re-evaluation based on visible losses and hemodynamic parameters. This aggressive approach was shown to result in the closest estimate of actual blood loss values in a case simulation scenario; however, clinicians still significantly underestimated the ongoing blood loss. “Gut feeling,” even when knowingly adjusted to a higher value than “initially believed,” is extremely unreliable and has been shown to have little correlation to actual blood loss, often underestimating by 50%. A multidisciplinary effort, including obstetricians, nurses, and anesthesiologists, should be organized early in the course of an obstetric hemorrhage, involving other services as necessary (e.g., laboratory, blood bank, perfusion, ICU). This will allow attention to the individual aspects of the hemorrhage event, including finding and controlling the source of bleeding, hemodynamic and pharmacologic management of the patient, blood and fluid replacement, laboratory testing, and ordering/obtaining blood products and supplies, by professionals working in their fields of expertise and familiarity, instead of one person (usually the obstetrician) trying to deal with all these issues at the same time. The need for continued communication between team members cannot be emphasized enough, and can and does fail even in the best, most practiced of units. The obstetrician has the best view of the field and can give feedback to the anesthesiologist about the extent of the ongoing bleeding. The anesthesiologist has more information on the hemodynamic picture and may ask for temporizing measures (such as temporary tamponade of the bleeding source) to allow catch-up with volume resuscitation or may point out ongoing undetected hemorrhage (based on unstable hemodynamics in spite of ongoing resuscitation) when the bleeding appears to be controlled on the field. Nursing staff is almost always the most aware of the issues with obtaining laboratory results or blood products.

Normovolemic resuscitation is the goal in obstetric patients. There is evidence in the trauma literature that some patient subgroups, for example, penetrating truncal injury, ruptured abdominal aortic aneurysm, may do better when volume resuscitation is limited before the therapeutic intervention, as such management may limit blood loss. No such evidence is available at present for obstetric patients. Hemo-
globin levels above 8 g/L are believed to be safe and well tolerated. Early use of coagulation factors in obstetric hemorrhage has been emphasized (although often ignored) for half a century and remains recommended practice.6

Oxytocin is the drug of first choice in the treatment of uterine atony. The ED95 of oxytocin in non-laboring patients undergoing elective cesarean sections was found to be only 0.35 IU,7 whereas that in women undergoing cesarean delivery after arrest of labor during which they had received oxytocin was an order of magnitude higher, but still less than 5 IU.8 Although these result cannot be easily converted to use in patients with prolonged, oxytocin-augmented labor who are hemorrhaging, the response to oxytocin is widely regarded to be the function and status of uterine oxytocin receptors rather than the plasma concentration of oxytocin,9 so it is reasonable to assume that, the longer the exposure and higher the dose of oxytocin to which the parturient has been exposed, the more she will need to receive to facilitate uterine contraction, and the higher the risk of needing alternative or additional drugs. Oxytocin is a potent vasodilator, and the preservative chlorbutanol has also been shown to have vasodilatory and negative inotropic effects. These factors should be considered before giving oxytocin as an IV bolus in a hypovolemic, bleeding patient.9,10 In a recent Confidential Enquiry into Maternal Death from the UK, two maternal deaths were attributed to oxytocin given as a bolus during postpartum hemorrhage.11 A study of the hemodynamic effects of a 5 U oxytocin bolus compared with a “slow” (5-minute) infusion of the same dose during cesarean section demonstrated significantly greater tachycardia and hypotension in the bolus group.12 In another recent clinical study, a 10 U bolus of oxytocin produced tachycardia, chest pain, hypotension, and ECG signs of myocardial ischemia in healthy (and nonhemorrhaging) women at cesarean section.13 We believe that bolus oxytocin should rarely, if ever, be administered during significant hemorrhage. In our practice, we use controlled infusions of 60 IU/L oxytocin and administer complementary ecologic agents if the response is inadequate. Ergot alkaloids (methylergonovine in the USA) are the obvious first choice as they elevate blood pressure, a usually desirable side effect in a bleeding, hypovolemic, hypotensive patient. Although the recommended dose and route of administration is 200 μg intramuscularly, diluting methylergonovine to a final concentration of 10-20 μg/mL allows careful intravenous titration rather than single-dose IM administration and has been used with no significant sequelae by one of the authors for several years in patients with preeclampsia and other forms of hypertension: a population where methylergonovine is considered “contraindicated.” With this strategy, one can detect undesired hypertensive/vasoconstrictive side effects early, and drug administration can be stopped. This is perhaps even most important in patients with a predilection to coronary vasospasm, described more commonly in the Asian population where methylergonovine can cause myocardial ischemia. There may well be specific genetic determinants of coronary response to methylergonovine and other coronary vasoconstrictors.14 Prostaglandin analogs, whether intramuscular carboprost (Hemabate®) or buccal or rectal misoprostol, have also been shown to enhance uterine contractility in scenarios where oxytocin was ineffective. Local availability and experience is usually what determines the choice of alternatives to oxytocin.

**Anticipated Obstetric Hemorrhage**

**High-Risk: “Expected” Hemorrhage**

The advent of ultrasound and other advances in imaging have resulted in improved and increased antepartum diagnosis of a variety of conditions associated with increased risk for bleeding, including placenta previa, placenta accreta, vasa previa, etc.15 Placenta accreta (and especially increta/percreta) ranks chief among these conditions in risk for massive, sometimes uncontrollable blood loss. Ninety percent of patients with placenta percreta will lose more than 3000 mL at cesarean section/hysterectomy.16 Therefore, it is often helpful to employ additional imaging modalities, typically MRI, to attempt to stratify patient risk and plan anesthetic management based on the degree of invasion suggested. It should be noted, however, that, although it seems reasonable to use MRI to quantitatively assess the extent of placental abnormalities, or surgical complexity and complications.

Whenever possible, any pregnant woman with a significant risk for major hemorrhage, and certainly any with suspected placental implantation abnormalities, should receive anesthesiological consultation before the delivery date. While admitting the inaccuracies and lack of specificity of all imaging techniques, in cases where the suspicion for placenta percreta is high, a surgical and anesthetic plan that is both cognizant of and prepared for rapid, massive transfusion of blood products, complications of disseminated intravascular coagulopathy (DIC), transfusion-related acute lung injury (TRALI) and adult respiratory distress syndrome (ARDS), renal failure, myocardial and cerebral ischemia, and abdominal visceral damage (ureters, bladder, and bowel) is required. This typically involves, in addition to standard monitoring (noninvasive blood pressure, SpO2, ECG), a general anesthetic from the outset with a secured airway, invasive arterial blood pressure monitoring, central venous large-bore access, a transfusion-assist device, in-line solution heaters, several infusion pumps preloaded with vasopressors (norepinephrine, vasopressin), a “bedside” portable arterial blood gas, hemoglobin, and electrolyte analyzer, and availability of intensive care postoperatively (Table 2). When a presumed placenta percreta is thought to involve multiple organs of often indeterminate blood supply or when placental invasion may preclude accessible surgical control of hemorrhage (even with planned hysterectomy), our practice often includes preoperative bilateral femoral arterial sheath placement under the direction of interventional radiology. These sheaths allow the direction of catheters for intraoperative fluoroscopically directed arterial occlusion embolization to prevent exsanguination.17 At our institution, the anesthesiology team typically accompanies the parturient to the interventional radiology suite the morning of the operation, and we perform a spinal anesthetic to insure that the
patient is comfortable during the procedure, and perhaps more importantly, that she does not accidentally move during arterial sheath placement and manipulation. A spinal dose of approximately 7.5 mg of hyperbaric bupivacaine with 10-20 μg of fentanyl and 200-300 μg of preservative-free morphine (for postoperative analgesia) is sufficient (about 60% of a cesarean section dose), sometimes with some mild systemic sedation (midazolam, 1-3 mg, fentanyl, 50-100 μg). The spinal anesthetic is performed with a small needle (25- to 27-G Whitacre), and we generally do not opt for a combined spinal–epidural procedure, even though one could imagine benefits from an epidural catheter for postoperative analgesia. The reasoning is that the chance for intraoperative and postoperative coagulopathy is relatively high and carries with it a risk for an epidural hematoma in the presence of an indwelling catheter. The length of the interventional radiology procedure, plus the time until transport to the operating room, induction of anesthesia, placement of lines, and delivery of the neonate results in a period of several hours between the spinal puncture and any possible development of coagulopathy, more than sufficient time for clot formation if there is any vascular entry during the anesthetic procedure. There has been a recent case report of the cesarean delivery itself being performed in the interventional radiology suite with the sheath and catheters in place, a plan that would require significant modifications to most IR suites.\textsuperscript{18}

**Possible/Probable Hemorrhage**

In contrast, the anesthetic management for obstetric cases in which the suspicion for major blood loss is moderate necessitates that the anesthesiologist assess and balance the risks posed by precipitous exsanguination and the mode of anesthesia. The choice between a regional anesthetic and general anesthesia is often not an easy one. The “default” anesthetic for most cesarean sections in the Western world is, of course, a regional anesthetic: epidural or spinal. Evidence suggests that regional anesthesia is associated with improved morbidity and mortality outcomes for parturients undergoing cesarean section,\textsuperscript{19} and women generally prefer to be awake for the birth of the child. However, it is probably inappropriate and sometimes impossible to extrapolate these findings and preferences to cases where risks for morbidity associated with rapid blood loss are clearly high. In the face of rapid hemorrhage and resulting hypotension, the patient may become obtunded or otherwise suffer altered consciousness from cerebral ischemia, experience severe nausea from splanchic (or cerebral) ischemia, and respiratory distress from inadequate peripheral oxygen delivery and ventilation–perfusion mismatch in the pulmonary circulation. None of these are pleasant for the patient, and all are, in fact, dangerous in a patient undergoing a regional anesthetic, and may necessitate an urgent conversion from a regional anesthetic to a general anesthetic under conditions of duress in order to secure the airway as well as to restore oxygen supply–demand balance. There is the possibility that a general anesthetic induction performed in an already hypotensive and hypovolemic patient with evolving deficits in oxygen delivery may exacerbate the possibility for the development of myocardial ischemia, so the decision to convert from a regional anesthetic to a general anesthetic should usually be made “early” rather than “late,” while the hemodynamic and respiratory status is still relatively stable. This is of course, easier to say in theory than to perform in practice and is one of the more difficult decisions to make in a cesarean section that starts with a regional anesthetic and in which bleeding is becoming a major issue. A recent prospective study demonstrated that, even in young healthy parturients, the incidence of myocardial ischemia-induced injury (evidenced by significant and persistent elevations in cardiac troponin levels) was 51% among women experiencing severe postpartum hemorrhage (defined as an estimated blood loss of >1000 cc with concomitant hemodynamic derangement) and strongly correlated to the severity of hemorrhage.\textsuperscript{20} The development of myocardial ischemia may also be compounded by administration of uterotonic, which have been reported to result in coronary spasm.\textsuperscript{21,22} If a cesarean delivery with a preoperative assessment, such as “moderate risk of placenta increta,” is undertaken with a regional anesthetic, a reappraisal of the likelihood for massive hemorrhage before any attempts to remove the placenta are undertaken is essential so that a conversion to general anesthesia may be undertaken before the patient becomes unstable. Obviously, there will be times when a patient becomes unstable due to hemorrhage before general anesthesia is induced or considered; anesthetic management in that situation is similar to that in major trauma cases, with an induction and maintenance strategy aimed at attempting to maintain vascular tone, cardiac output, and recruitment of additional personnel, vascular access, and blood products.
When the preoperative and intraoperative suspicion for significant placental invasion is low (as in the case of a focal accreta), the benefits of regional anesthesia likely outweigh the risks posed by noncontrollable bleeding. Here, the usual advantages of regional anesthesia—avoiding complications with the maternal airway, postoperative analgesia, possibly reduced incidence of deep venous thrombosis, and maternal presence and maternal–fetal bonding—can be determinative. Our and others’ experiences support the safety of epidural anesthesia in appropriately evaluated moderate-risk patients, illustrating that regional anesthesia via an epidural can be used in this scenario, and in the case of planned cesarean hysterectomy. For cases of focal accreta/increta in an otherwise healthy parturient with a favorable airway, we will typically perform a CSE regional anesthetic with invasive arterial blood pressure monitoring, two peripheral venous large-bore cannulas (16 G or larger), a transfusion-assist device stand by, in-line solution heaters, several infusion pumps preloaded with a vasopressor (phenylephrine) and uterotonics, and a portable ABG device. However, general anesthesia is warranted if the airway appears difficult, there is coagulopathy, or if the patient refuses regional anesthesia. Airway alterations during a cesarean hysterectomy that can arise. In the absence of central venous access, administration of in-line air. Attempting to maintain temperature of the infusate. This device has been shown to be superior to a reservoir of 3000 mL and can generate flows of up to 500 mL/min while maintaining physiological temperature (37°C) of the infusate. This device has been shown to be superior to a more “traditional” pressure infusion device, such as the Level 1 rapid infuser (SIMS Level 1, Inc, Rockland, MA) with regard to maintaining temperature at high flow and management of in-line air. Attempting to maintain temperature near normal is critical because hypothermia promotes coagulopathy, leading to a vicious cycle of infusing cold blood, which exacerbates more bleeding. As a practical matter, it is easier to keep a reservoir filled with products than to “hang” individual units of PRBCs and FFP. The threshold to initiate transfusion requires both an appraisal of the degree of surgical hemostasis achieved in the operative field and the patient’s hemodynamic status. For cases where blood loss is expected, transfusion is often commenced earlier, because the chance of avoiding blood products appears negligible, and the risk of “falling behind” is much greater. In the presence of vital sign derangements suggestive of acute major hemorrhage (hypotension unresponsive to moderate vasopressor support, tachycardia above 130 bpm, etc.) and the absence of overt blood loss visible in the operative field, it is advisable to consider that significant blood loss is occurring into the vaginal vault through an incompetent cervix, and a vaginal examination should be performed. Communication between anesthesiologist and surgeon is essential in these situations to confirm that “stability” on one side of the drapes appears to correlate with “stability” on the other.

Monitoring ongoing blood loss and its metabolic effects is difficult, and results from tests sent to hospital laboratories are rarely available in a timely manner. We now use point-of-care devices to trend hemoglobin level, ionized calcium, sodium, and potassium concentrations, pH, PO2, PCO2, and base deficit in response to ongoing bleeding and transfusion. We use the i-STAT device (Abbott Laboratories, Abbott Park, IL). The i-STAT hemoglobin concentration results have been available. All blood components are screened (checked) by two people to confirm that products are correctly paired to the patient before the patient is brought to the operating room. Our standard practice for cases with large anticipated blood loss (eg, suspected placenta percreta) is to keep 20 U of cross-matched PRBCs and 20 U of FFP in a refrigerator or cooler in the OR suite, 12 U of platelets at room temperature, and to have direct communication with the blood bank to have additional blood products available on request. For some lower-risk cases (eg, suspected accreta, very unlikely further invasion), 10 U of PRBCs, 10 U of FFP, and 6 U of platelets may be sufficient to start with, assuming more is readily available if and when bleeding starts. Given the alacrity with which blood loss can occur, it is an essential to have a rapid transfusion-assist device connected and primed for use before the advent of hemorrhage. Especially for major cases, we prefer a device with an occlusive in-line-pump and reservoir (similar to a cardiopulmonary bypass machine reservoir), so that multiple units of products can be “loaded” at once, and which also allows faster, more automatic flow rates. We currently recommend the use of the FMS 2000 (Belmont Instrument Corporation, Billerica, MA), which has a reservoir of 3000 mL and can generate flows of up to 500 mL/min while maintaining physiological temperature (37°C) of the infusion. This device has been shown to be superior to a more “traditional” pressure infusion device, such as the Level 1 rapid infuser (SIMS Level 1, Inc, Rockland, MA) with regard to maintaining temperature at high flow and management of in-line air. Attempting to maintain temperature near normal is critical because hypothermia promotes coagulopathy, leading to a vicious cycle of infusing cold blood, which exacerbates more bleeding. As a practical matter, it is easier to keep a reservoir filled with products than to “hang” individual units of PRBCs and FFP. The threshold to initiate transfusion requires both an appraisal of the degree of surgical hemostasis achieved in the operative field and the patient’s hemodynamic status. For cases where blood loss is expected, transfusion is often commenced earlier, because the chance of avoiding blood products appears negligible, and the risk of “falling behind” is much greater. In the presence of vital sign derangements suggestive of acute major hemorrhage (hypotension unresponsive to moderate vasopressor support, tachycardia above 130 bpm, etc.) and the absence of overt blood loss visible in the operative field, it is advisable to consider that significant blood loss is occurring into the vaginal vault through an incompetent cervix, and a vaginal examination should be performed. Communication between anesthesiologist and surgeon is essential in these situations to confirm that “stability” on one side of the drapes appears to correlate with “stability” on the other.

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Transfusion Therapy

Regardless of the mode of anesthesia used for these cases, it is prudent to have sufficient blood products immediately available. All blood components are screened (checked) by two people to confirm that products are correctly paired to the patient before the patient is brought to the operating room. Our standard practice for cases with large anticipated blood loss (eg, suspected placenta percreta) is to keep 20 U of cross-matched PRBCs and 20 U of FFP in a refrigerator or cooler in the OR suite, 12 U of platelets at room temperature, and to have direct communication with the blood bank to have additional blood products available on request. For some lower-risk cases (eg, suspected accreta, very unlikely further invasion), 10 U of PRBCs, 10 U of FFP, and 6 U of platelets may be sufficient to start with, assuming more is readily available if and when bleeding starts. Given the alacrity with which blood loss can occur, it is an essential to have a rapid transfusion-assist device connected and primed for use before the advent of hemorrhage. Especially for major cases, we prefer a device with an occlusive in-line-pump and reservoir (similar to a cardiopulmonary bypass machine reservoir), so that multiple units of products can be “loaded” at once, and which also allows faster, more automatic flow rates. We currently recommend the use of the FMS 2000 (Belmont Instrument Corporation, Billerica, MA), which has a reservoir of 3000 mL and can generate flows of up to 500 mL/min while maintaining physiological temperature (37°C) of the infusate. This device has been shown to be superior to a more “traditional” pressure infusion device, such as the Level 1 rapid infuser (SIMS Level 1, Inc, Rockland, MA) with regard to maintaining temperature at high flow and management of in-line air. Attempting to maintain temperature near normal is critical because hypothermia promotes coagulopathy, leading to a vicious cycle of infusing cold blood, which exacerbates more bleeding. As a practical matter, it is easier to keep a reservoir filled with products than to “hang” individual units of PRBCs and FFP. The threshold to initiate transfusion requires both an appraisal of the degree of surgical hemostasis achieved in the operative field and the patient’s hemodynamic status. For cases where blood loss is expected, transfusion is often commenced earlier, because the chance of avoiding blood products appears negligible, and the risk of “falling behind” is much greater. In the presence of vital sign derangements suggestive of acute major hemorrhage (hypotension unresponsive to moderate vasopressor support, tachycardia above 130 bpm, etc.) and the absence of overt blood loss visible in the operative field, it is advisable to consider that significant blood loss is occurring into the vaginal vault through an incompetent cervix, and a vaginal examination should be performed. Communication between anesthesiologist and surgeon is essential in these situations to confirm that “stability” on one side of the drapes appears to correlate with “stability” on the other.

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shown to be not as accurate as clinical laboratory methods in some clinical scenarios, notably in critical care and during cardiopulmonary bypass, but our experience in obstetric hemorrhage cases has not revealed any important discrepancies, and we routinely use the immediately available information about hemoglobin and blood gases to make clinical decisions in the operating room.

Traditional transfusion guidelines suggest switching to a 1:3 ratio of FFP to PRBC and administration of 6 U of platelets once blood replacement exceed 10 U of PRBCs. New (and some old) evidence suggests that, in massive hemorrhage, these ratios underestimate the importance of FFP and platelets. Although no data have emerged yet from obstetric hemorrhage cases examining outcomes based on transfusion practice, several studies have emerged examining transfusion protocols used during massive hemorrhage in trauma patients. A retrospective review of 246 patients at a US Army combat support hospital who received massive transfusion (defined as ≥10 U of PRBC in 24 hours) suggests that higher FFP-to-PRBC ratios may be beneficial to prevent coagulopathy and improve survival. They stratified patients with equivalent Median Injury Severity Scores (ISS = 18) into three groups based on the plasma-to-PRBC ratios used during transfusion: for the low ratio group, the plasma-to-PRBC median ratio was 1:8 (interquartile range, 0:12-1:5), for the medium ratio group, 1:2.5 (interquartile range, 1:30-1:2.3), and for the high ratio group, 1:1.4 (interquartile range, 1:1.7-1:1.2) (P < 0.001). Overall mortality rates were 65%, 34%, and 19% for the low, medium, and high plasma groups (P < 0.001), and plasma-to-PRBC ratio was independently associated with survival by linear regression analysis (odds ratio 8.6, 95% confidence interval 2.1-35.2). Two additional reports this year corroborate these findings, and suggest that these results are likely applicable to civilian medical practice. A retrospective, multicenter review of 466 trauma patients found that 30-day survival was increased in those patients who received either high plasma-to-PRBC ratio (≥1:2) relative to those with low plasma-to-PRBC ratio (<1:2) or a high platelet-to-PRBC ratio (≥1:2) relative to those with low platelet:PRBC ratio (<1:2) (low: 40.1% v. high: 59.9%, P < 0.01) and that combination of high plasma- and high platelet-to-PRBC ratios were associated with decreased truncal hemorrhage, mechanical ventilation, intensive care unit, and overall hospital stay (P < 0.05). However, no change in multiple organ failure deaths was observed. In a cohort of 259 trauma patients, those who received a 2:3 FFP:PRBC ratio (n = 64) had a significant reduction in 30-day mortality compared with those who received less than this ratio (n = 195): 41% versus 62%. In addition, patients receiving platelet:PRBC at a ratio of 1:5 or greater (n = 63) had a lower 30-day mortality when compared with those who received less than this ratio (n = 196; 38% vs. 61%). Given the propensity for obstetric patients to develop coagulopathy and disseminated intravascular coagulation, and in the absence of actual studies in parturients, the existing evidence suggests that, if massive obstetric blood losses occur requiring transfusion in excess of 10 U of PRBCs, an increased FFP:PRBC and platelet:PRBC ratio will likely improve survival and reduce transfusion induced coagulopathy. When we anticipate blood replacement to exceed 10 U for the case, we start transfusions (ie, load the reservoir of the rapid infusion pump) with close to a 1:1 ratio of plasma and PRBCs from the beginning of blood replacement. There is little downside in starting with 1:1 FFP:PRBC from the outset in obstetric cases with presumed high blood loss; should the blood loss be found significantly less than expected, the possible adverse effects of administering a few units of unnecessary FFP (transmission of disease, severe allergic reaction) are less likely or less significant (mild allergic reaction) than allowing coagulopathy to develop in cases that turn out to result in massive hemorrhage. Platelet therapy (6-10 U at a time) is usually considered as the total PRBC units used approaches 10 U, and platelet counts are monitored frequently thereafter to guide therapy. We also strongly consider initiating cryoprecipitate at that point. Because we have aggressively adopted this “high, early plasma” strategy, we have seen much less significant coagulopathy intra- and postoperatively, even in patients who have lost 10-25 L of blood and received 20-40 U of PRBC.

**Controversies in Management**

**Cell Salvage in Obstetrics**

There are many reasons to consider or favor cell salvage and reinfusion techniques in the case of major hemorrhage. The cost of cell salvage is less than that of obtaining and processing homologous (blood bank) blood; there is no risk of incompatible transfusion or similar transfusion reactions; the risk of infection is reduced; and the blood available may bridge those periods when the blood bank delivery of product “falls behind” the blood loss. Cell salvage may be particularly useful in cases where homologous blood use is difficult or impossible, such as for Jehovah’s Witnesses or patients who have multiple antibodies. In some cases of moderate bleeding, cell salvage may avoid the need for homologous transfusion altogether. Cell salvage is used in most major surgical anesthesia subspecialties, but its use in obstetrics has been limited, chiefly due to concerns related to reinfusion of fetal red blood cells and amniotic fluid, and the difficulty of predicting which patients will require transfusion. Modern cell salvage processing removes most particulate contaminants and reduces fetal hemoglobin concentrations to levels of the same magnitude as those normally found in maternal blood. Most importantly, the current understanding of “amniotic fluid embolism” suggests that this syndrome is a rare anaphylactoid reaction to some fetal antigen rather than a predictable response to exposure to amniotic fluid. Exposure to amniotic fluid and fetal material is ubiquitous during cesarean section and probably all deliveries. Cell salvage during cesarean section has now been reported in hundreds of cases, with no significant complications reported. A decade ago, there was still concern over the wisdom of this technique in obstetrics, but in recent years, a consensus appears to have developed that there is no reason to hesitate to use cell salvage when major blood loss is expected and the equipment and personnel are available. In a recent published debate regarding the use of cell salvage in obstetrics, the argument against cell salvage did not involve serious...
medical or scientific objections, but rather raised economic and practical arguments against routine or widespread use of cell salvage, arguing that, although cell salvage was a good idea in cases of placenta accreta or other expected hemorrhage, there was no indication for routine use or for a requirement that such a device and program be present in every obstetric unit. We have used cell salvage for more than a decade on almost all of our cases with suspected placental implantation abnormalities, and many others where significant hemorrhage was suspected, and have seen no obvious complications.

**Factor VII**

Synthetic, recombinant activated factor VII (rFVIIa) is a relatively new treatment for coagulopathy and intractable bleeding. Factor VII mediates coagulation in the presence of tissue factor, so theoretically works only (or mostly) at the actual site of vascular injury, activating coagulation factors IX and X and platelets. The specific indications for this very expensive drug in the United States is bleeding in patients with Hemophilia A and with inhibitors to coagulation, but it is being increasingly used “off-label” for a variety of severe hemorrhage indications, including primary postpartum hemorrhage, even without any clear coagulopathy. Case reports have suggested almost miraculous efficacy in helping to control massive bleeding, but the publication bias in case reports must be considered. Several recent reviews suggest that rFVIIa is quite effective (70-90%) in stopping previously uncontrollable postpartum hemorrhage, even without any clear coagulopathy. Some suggested guidelines for the use of rFVIIa have been published in Australia. Given the cost of this therapy (up to tens of thousands of dollars per patient), and its known potential to lead to thrombosis, which could be exacerbated in pregnancy, its role in postpartum hemorrhage needs to be clarified. Our approach thus far has been to get the required blood bank preapproval for the use of rFVIIa in patients at risk should it be deemed necessary, but we have not used rFVIIa thus far.

**Normovolemic Hemodilution**

Normovolemic hemodilution involves the immediate preoperative removal of blood, usually 2-3 U, and replacement by crystalloid or colloid solution in a 2:1 or 3:1 ratio. The concept is to allow patients to bleed blood at a lower hematocrit and replace near the end of surgery with blood containing a higher starting hemoglobin concentration. This strategy has been shown to decrease blood product usage and even avoid the need for transfusion in some patients, but the risk–cost–benefit profile is far from clear. There has been limited experience with normovolemic hemodilution in pregnant patients, because of the difficulty in identifying patients who are likely to bleed, especially those likely to bleed moderately (20-50% of blood volume), who might benefit the most from the possible avoidance of transfusion if normovolemic hemodilution were to be performed. Reports in obstetrics have been limited to women who refuse blood product transfusion, such as Jehovah’s Witnesses. One could imagine potential utility in those with blood difficult to cross-match because of antibodies. There are some technical issues that need to be considered before employing technique involving such apparent minutiae as the connection of the blood collection bags to the removal ports form the patient, and ability to maintain good mixing of the collection bag to ensure anticoagulation. In the case of Jehovah’s Witnesses, it may be necessary to maintain a physical connection of the collection bag to the patient at all times, a consideration that may also apply to such patients’ consent to cell salvage techniques.

**Conclusion**

The anesthesiologist should play a key role in the management of obstetric hemorrhage. As with almost all medical and surgical crises or emergencies, the principles of preparation and planning when possible, early notification when necessary, and good communication and teamwork at all times are the keys to successful outcomes.

**References**

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