Postpartum hemorrhage: Management approaches requiring laparotomy

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INTRODUCTION — Postpartum hemorrhage (PPH) is an obstetric emergency with many potentially effective interventions for management (table 1). In patients with PPH who have had a vaginal birth or whose cesarean delivery has been completed, medical and minimally invasive approaches are the preferred treatment approaches; laparotomy is generally a last resort that is performed when less invasive interventions have failed. During cesarean delivery, uterotonic drugs and manual uterine massage and compression are still the initial treatments for bleeding due to atony, but uterine compression sutures and other operative interventions for control of hemorrhage are performed sooner since the abdomen is already open.

This topic will discuss treatment approaches to PPH that require laparotomy. Medical and minimally invasive management of patients with PPH is reviewed separately (see "Postpartum hemorrhage: Medical and minimally invasive management"). An overview of issues related to PPH: incidence, pathogenesis, risk factors, clinical presentation and diagnosis, general principles of planning and management, morbidity and mortality, and recurrence, is also available separately. (See "Overview of postpartum hemorrhage".)

EVALUATION OF THE ABDOMEN — Laparotomy to assess and treat suspected pelvic bleeding is, in the author's opinion, best performed through a vertical midline incision to provide exposure of both the pelvis and abdomen. In patients at or post cesarean delivery, the existing incision is used, and extended if needed to provide adequate exposure.

A self-retaining retractor, such as a Balfour or Bookwalter, provides adequate lateral exposure. A posterior rupture is not readily visualized upon entering the abdomen so the entire uterus needs to be inspected carefully.

At laparotomy, the abdominal cavity is irrigated to remove blood and clots and inspected for the source of bleeding. The source of bleeding is usually readily apparent if pelvic, but may not be immediately recognized when it is retroperitoneal (including vaginal and vulvar hematomas), confined to the uterine cavity after vaginal delivery or after closure of the uterine incision at cesarean, or under surgical drapes. These sites should be actively evaluated in patients with compensated shock (normal blood pressure with increasing heart rate).

Intra-abdominal blood without an obvious uterine rupture or bleeding vessel may be due to hepatic or splenic rupture. (See "HELLP syndrome", section on 'Hepatic hematoma and rupture' and "Approach to the adult with splenomegaly and other splenic disorders", section on 'Splenic rupture'.)

TEMPORARY MEASURES FOR STABILIZING HEMODYNAMICALLY UNSTABLE PATIENTS — Severe bleeding often continues while the surgeon is preparing to perform and performing surgical procedures for controlling hemorrhage. Temporizing maneuvers should be attempted prior to performing any surgical

procedures, such as opening the retroperitoneum, which will take significant time before the source of bleeding is identified and/or controlled. Even the most simple-appearing hysterectomy in a patient with severe coagulopathy can be very difficult once the pelvis or retroperitoneum fills with blood and structures that were not bleeding start to bleed.

The following measures, in addition to fluid administration and transfusion of blood products, help to support the patient hemodynamically in preparation for and during surgical evaluation and treatment, and can be life-saving. The option chosen depends on the urgency to control bleeding, the source of bleeding (intrauterine versus extrauterine), and the surgeon's expertise and preference.

Patients at imminent risk of exsanguination

Manual aortic compression — If there is an imminent threat of exsanguination (ie, within a few minutes), the surgeon should compress the aorta against the vertebrae a few centimeters superior to the sacral promontory (figure 1); the bifurcation into the common iliac arteries is just distal to this point. Alternatively, the aorta can be compressed just below the renal arteries, which will minimize collateral flow to the uterus from the ovarian and inferior mesenteric arteries. Compression at either site will slow the volume of bleeding and will afford a better opportunity for finding and controlling the source of hemorrhage. Compression just above the bifurcation may be easier to accomplish, but is less effective than below the renal arteries because of the extensive collateral blood supply to the uterus.

Resuscitative endovascular balloon occlusion of the aorta — An ultrasound directed, aortic balloon placement technique has been used in trauma (military and civilian) and emergency room scenarios. Minimal data on the use of this technique in obstetrics are available, but suggest that in desperate situations, particularly in low-resource environments where interventional radiology and blood banking are unavailable, resuscitative endovascular balloon occlusion of the aorta (REBOA) by appropriately trained obstetricians may offer a minimally invasive approach to resuscitation. It may also be used prophylactically before surgery in women with a morbidly adherent placenta. (See "Postpartum hemorrhage: Medical and minimally invasive management", section on 'Consider resuscitative endovascular balloon occlusion of the aorta'.)

Intermittent intraaortic balloon occlusion — Intraaortic balloon catheters have been used intraoperatively to stabilize patients in extreme emergencies where death from exsanguination is imminent, but evidence of safety and efficacy is limited to case reports [1,2].

A balloon catheter can be placed directly into the aorta at the bifurcation using a Seldinger technique (initial needle followed by a guidewire over which the balloon catheter is inserted). The catheter is advanced up the aorta and the balloon is positioned below the renal arteries and above the ovarian and inferior mesenteric arteries under direct vision and palpation, and then inflated. This position should ensure substantial reduction in uterine blood flow (figure 1). As discussed above, placing the intraaortic balloon just above the aortic bifurcation may not substantially reduce uterine blood flow because of the extensive collateral blood supply to the uterus. For example, the ovarian arteries supply the uterus via the utero-ovarian branches (figure 2); therefore, if the ovarian arteries are not occluded, then uterine blood flow may not be substantially reduced despite uterine artery, and even internal iliac artery, ligation. Similarly, the inferior mesenteric artery is continuous with the uterine arterial collateral system via the superior rectal artery and its posterior collaterals (lumbar and median sacral arteries); therefore, uterine blood flow may not be substantially reduced if the inferior mesenteric artery is not occluded.

When the patient has been resuscitated, the balloon is deflated intermittently to prevent ischemic limb or colon complications from aortic occlusion, and distal pulses are monitored frequently. Consultation with a vascular surgeon is recommended, especially prior to removal of the catheter in case repair of the insertion site is needed.

Patients at nonimminent risk of exsanguination

Uterine tourniquet — Tourniquets have been used to control bleeding at myomectomy, and for other types of uterine hemorrhage, and may be useful as a temporizing measure in PPH [3-5]. A Penrose drain or urinary catheter is placed as low as possible around the lower uterine segment without incorporating the urinary bladder, and then the two ends are pulled in opposite directions and as tightly as possible around the corpus to mechanically occlude the vascular supply. A second or third tourniquet can also be applied, as needed. The tourniquet can be held in place with a clamp (figure 3). This procedure markedly reduces blood loss and allows time for the anesthesia team members to catch up with transfusion requirements. When the patient is hemodynamically stable, the tourniquet is removed and the surgical procedure is completed. (See "Techniques to reduce blood loss during abdominal or laparoscopic myomectomy", section on 'Tourniquets and clamps'.)

Intrauterine balloon tamponade — Commercially available and improvised devices have been used successfully to tamponade bleeding from the uterine cavity after vaginal or cesarean delivery. For each device, the intrauterine balloon is filled until bleeding is controlled; continued excessive bleeding indicates that tamponade is not effective. Intrauterine balloon tamponade has been used alone and in combination with uterine compression sutures ("uterine sandwich"). The technique is described separately. (See "Intrauterine balloon tamponade for control of postpartum hemorrhage", section on 'After cesarean delivery'.)

Ligation of uterine and utero-ovarian arteries — Ligation of the uterine and utero-ovarian arteries can decrease uterine bleeding by reducing perfusion pressure in the myometrium. It will not control bleeding from uterine atony or placenta accreta, but may decrease blood loss while other interventions are being attempted. It does not harm the uterus and does not appear to impact reproductive function [6]. (See 'Laceration of the uterine artery or utero-ovarian artery branches' below.)

Pelvic packing — Pelvic packing to create tamponade pressure exceeding arterial pressure can control bleeding from small pelvic arteries. It can be useful as a temporizing measure in the management of broad ligament or retroperitoneal hematomas, lacerations that are difficult to repair because of their location or friable tissue, bleeding related to coagulopathy while coagulation factors are being replaced, and posthysterectomy bleeding. The technique is described below. (See 'Management of persistent bleeding after hysterectomy' below.)

Clamp across utero-ovarian ligaments — Placing a large clamp across the utero-ovarian ligaments is a rapid and simple means of occluding uterine blood flow through ovarian artery collaterals; however, it also effectively ligates the fallopian tubes (figure 4), precluding future conception without in vitro fertilization.

Role of internal iliac artery ligation — This technique is challenging even for an experienced pelvic surgeon, especially when there is a large uterus, a transverse lower abdominal incision, ongoing pelvic hemorrhage, or the patient has a high body mass index. Successful and safe bilateral hypogastric ligation becomes even more difficult when attempted by a surgeon who rarely operates deep in the pelvic retroperitoneal space [7]. For these reasons, uterine compression sutures, uterine artery ligation, and arterial embolization have largely replaced this procedure.

Bilateral ligation of the internal iliac arteries (hypogastric arteries) reduces the pulse pressure of blood flowing to the uterus [8]. The utility of the procedure may be compromised when there are extensive collateral vessels (such as in placenta percreta). Reverse filling of the internal iliac arteries has been reported beyond the point of ligation via branches of the external iliac artery (inferior epigastric, obturator, deep circumflex iliac, and superior gluteal arteries) [9,10].

A technical description of the procedure is available separately. (See "Management of hemorrhage in gynecologic surgery", section on 'Internal iliac artery ligation'.)

Role of intraoperative cell salvage — Intraoperative cell salvage may be arranged before laparotomy or requested during laparotomy. Institutions should have designated personnel, which may include cross-trained operating room employee (eg, an anesthesia technician) or a member of a specialist service (eg, an

extracorporeal technologist or perfusionist), who are called to manage this equipment and who follow written policies and procedures for proper collection, labeling, and storage of the collected blood.

Intraoperative cell salvage with a leukocyte filter and autotransfusion can reduce the use of allogeneic blood, but its use is investigational in the obstetrical setting [11-15]. Although there is a theoretical concern that reinfusing amniotic fluid may cause amniotic fluid embolism, this has been documented only once [16]. Risk of maternal infection from infusion of bacterial contamination is also minimal. Salvaged blood may contain fetal erythrocytes [15], but this is not a major concern, as Rh(D) alloimmunization in an Rh(D)-negative mother can be prevented by administration of anti-D immunoglobulin. ABO incompatibility reactions cannot be prevented, but are unlikely to be serious because the volume of fetal blood contamination is small and A and B antigens/antibodies are not fully developed at birth. These risks are probably less than or similar to those from allogeneic transfusion. (See "Surgical blood conservation: Blood salvage".)

ETIOLOGY-BASED MANAGEMENT

General principles — A variety of surgical interventions are effective for controlling PPH [17]. Clinicians should use their clinical judgment in deciding whether to expend time attempting conservative interventions in a patient with severe hemorrhage who may be better served by hysterectomy, such as women with a morbidly adherent placenta or uterine rupture.

Cessation of hemorrhage depends on reversal of any coagulopathy, so every effort should be made to reverse contributing factors such as hypothermia, acidosis, and lack of clotting factors. Even if bleeding cannot be completely controlled initially, as long as more blood and blood products are infused than lost, hemodynamic stability can be achieved and maintained. (See "Postpartum hemorrhage: Medical and minimally invasive management", section on 'Transfuse red blood cells, platelets, plasma' and "Postpartum hemorrhage: Medical and minimally invasive management", section on 'Correct clotting factory deficiencies'.)

Myometrial lacerations — Serious hemorrhage from the uterine incision is generally caused by lateral extension of the incision. Bleeding from a hysterotomy incision can generally be controlled by suture ligation. The angles of a transverse incision should be clearly visualized to ensure that they, and any retracted vessels, are completely ligated. This generally requires exteriorization of the uterus with gentle traction and adequate lateral retraction.

Given the proximity of the ureter to the vaginal angle and bladder reflection, placement of hemostatic sutures laterally to control bleeding from an extension of a hysterotomy laceration should be carried out with extreme caution. If possible, the ipsilateral ureter should be identified before the bleeding is controlled and, once the hemorrhage has been controlled, the integrity of the ureter should be ensured. (See 'Post-laparotomy inspection' below.)

Laceration of the uterine artery or utero-ovarian artery branches — Bilateral ligation of the uterine vessels (O'Leary stitch) is the preferred approach for controlling PPH from laceration of the uterine artery or branches of the utero-ovarian artery [18,19]. It is preferable to internal iliac artery ligation because the uterine arteries are more readily accessible, the procedure is technically easier, and there is less risk to major adjacent vessels and the ureters. (See 'Role of internal iliac artery ligation' above.)

After identification of the ureter, a large curved needle with a #0 polyglycolic acid suture is passed through the lateral aspect of the lower uterine segment as close to the cervix as possible and then back through the broad ligament just lateral to the uterine vessels. If this does not control bleeding, the vessels of the utero-ovarian arcade are similarly ligated just distal to the cornua by passing a suture ligature through the myometrium just medial to the vessels, then back through the broad ligament just lateral to the vessels, and then tying to compress the vessels (figure 5).

Bilateral ligation of the arteries and veins (uterine and utero-ovarian) is successful in controlling hemorrhage in over 90 percent of patients [19,20] and does not appear affect future reproductive function [6]. Uterine necrosis and placental insufficiency in a subsequent pregnancy have not been described as complications

[20,21]. However, there is a single case report of ovarian failure and development of intrauterine synechiae after postpartum ligation of the uterine, utero-ovarian, and ovarian arteries for PPH related to atony [22].

Atony — The interventions for reduction and control of bleeding due to atony are applied in rapid sequence until bleeding is controlled, which may be the result of the cumulative combined effect of multiple interventions. All patients with PPH related to atony receive uterine massage/manual compression and administration of uterotonic drugs and tranexamic acid. (See "Postpartum hemorrhage: Medical and minimally invasive management".)

If these measures do not control bleeding and the patient is hemodynamically stable, we rapidly moving on to placement of uterine compression sutures, which are an effective method for reducing uterine blood loss related to atony.

If the patient is hemodynamically unstable, temporizing measures such as placement of a uterine tourniquet, insertion of an intrauterine balloon for tamponade, and/or ligation of the uterine and utero-ovarian arteries can reduce ongoing heavy blood loss before placing compression sutures, and may obviate the need for them. (See 'Patients at nonimminent risk of exsanguination' above.)

Uterine compression sutures — The B-Lynch suture is the most common technique for uterine compression; several variations of this technique have been described and no technique has been proven significantly more effective than another [23]. Generally, longitudinal sutures are easier to place and safer than transverse sutures, but this may not always be the case.

Procedure-related complications, such as uterine necrosis, erosion, and pyometra, have been reported rarely [24-29]. Limited follow-up of women who have had a uterine compression suture suggests that there are no adverse effects on fertility or future pregnancy outcome [6,30]. Although uterine synechiae have been reported on postpartum hysteroscopy or hysterosalpingogram, some of these women may have also had curettage, which could account for the finding [31].

B-Lynch suture — The B-Lynch suture envelops and compresses the uterus, similar to the result achieved with manual uterine compression [32]. In case reports and small series, it has been highly successful in controlling uterine bleeding from atony when other methods have failed [32-36]. The technique is relatively simple to learn, appears safe, preserves future reproductive potential, and does increase the risk of placentation-related adverse outcomes in a subsequent pregnancy [37,38]. It should only be used in cases of uterine atony; it will not control hemorrhage from placenta accreta. It will not prevent postpartum hemorrhage in future pregnancies [37].

A large Mayo needle with #1 or #2 chromic catgut (or any absorbable suture if catgut is unavailable) is used to enter and exit the uterine cavity laterally in the lower uterine segment (figure 6). A large suture is used to prevent breaking and a rapid absorption is important to prevent a herniation of bowel through a suture loop after the uterus has involuted.

The suture is looped over the fundus and re-enters the lower uterine cavity through the posterior wall. The suture then crosses to the other side of the lower uterine segment, exits through the posterior wall, and is looped back over the fundus to enter the anterior lateral lower uterine segment opposite and parallel to the initial bites. The free ends are pulled tightly and tied down securely to compress the uterus, assisted by bimanual compression.

Proper patient positioning (legs apart, patient flat, or, if stable, in slight reverse Trendelenburg) will enhance the ability to assess the efficacy of these efforts by allowing for better visualization of persistent vaginal bleeding.

The technique has been used alone and in combination with balloon tamponade. This combination has been called the "uterine sandwich." (See "Intrauterine balloon tamponade for control of postpartum hemorrhage", section on 'External compression plus internal tamponade'.)

Other uterine compression suture techniques — Other techniques have been reported in small case series and represent modifications of the B-Lynch suture [34,39-46].

- **Hayman** described placement of two to four vertical compression sutures from the anterior to posterior uterine wall without hysterotomy (figure 7); thus, this is a good choice for surgical treatment of atony after a vaginal delivery [39,40,47]. A transverse cervicoisthmic suture can also be placed if needed to control bleeding from the lower uterine segment.

- **Pereira** described a technique in which a series of transverse and longitudinal sutures of a delayed absorbable multifilament suture are placed around the uterus via a series of bites into the subserosal myometrium, without entering the uterine cavity (figure 8) [41]. Two or three rows of these sutures are placed in each direction to completely envelope and compress the uterus. The longitudinal sutures begin and end tied to the transverse suture nearest the cervix. When the transverse sutures are brought through the broad ligament, care should be taken to avoid damaging blood vessels, ureters, and fallopian tubes. The myometrium should be manually compressed prior to tying down the sutures to facilitate maximal compression.

- **Cho** described a technique using multiple squares/rectangles (figure 9) [43,48].

Retroperitoneal bleeding — Identification of an isolated bleeding point in the retroperitoneum is often impossible. It is rarely advisable to open the retroperitoneum or attempt dissection of an expanding retroperitoneal hematoma in a coagulopathic, hemodynamically unstable patient. The temporizing procedures described above can be used to stabilize the patient before beginning retroperitoneal surgery. (See 'Temporary measures for stabilizing hemodynamically unstable patients' above.)

If a discrete retroperitoneal vessel is responsible for hemorrhage, it is clamped and ligated with appropriate suture material. Bleeding adjacent to the uterus without clear bleeding points can be managed by ligation of uterine vessels. If ineffective, ligation of the ipsilateral hypogastric artery usually stops the bleeding and avoids the delay associated with searching for the discrete source of bleeding. If bleeding does not respond to ipsilateral hypogastric artery ligation, then bilateral hypogastric artery ligation and/or pelvic packing may be necessary. Management of retroperitoneal bleeding is discussed in more detail separately. (See "Management of hematomas incurred as a result of obstetrical delivery", section on 'Retroperitoneal hematomas'.)

If time allows, when retroperitoneal bleeding is present and efforts at controlling retroperitoneal bleeding are necessary, ureteral stents may allow palpation of the ureters and placement of hemostatic sutures with more confidence.

Placental abnormalities

Morbidly adherent placenta — Management of the morbidly adherent placenta is reviewed separately. (See "Management of the morbidly adherent placenta (placenta accreta, increta, and percreta)".)

Placenta previa — Management of the placenta previa is reviewed separately. (See "Placenta previa: Management".)

POST-LAPAROTOMY INSPECTION — At the completion of the laparotomy and before closing the abdomen, the operative field should be inspected carefully for hemostasis. Microvascular bleeding usually can be controlled using topical hemostatic agents. (See "Management of hemorrhage in gynecologic surgery".)

The bladder and ureters should be identified and inspected. The ureter courses horizontally along the peritoneum 1 to 5 cm dorsal to the ovarian vessels and can be identified readily as it passes ventral to the bifurcation of the common iliac artery. Identification of bladder and/or ureteral injury is the same as during gynecologic surgery (visual inspection; possible cystoscopy, dye injection, stent placement to assess for

obstruction, ureterography). (See "Urinary tract injury in gynecologic surgery: Identification and management".)

ROLE OF HYSTERECTOMY — Hysterectomy is a definitive treatment of uterine bleeding. Regardless of the etiology of PPH, continued blood loss can lead to severe coagulopathy due to massive loss of coagulation factors. Severe hypovolemia, tissue hypoxia, hypothermia, electrolyte abnormalities, and acidosis can result, which further compromise the patient's status. If the patient is not already at laparotomy and has developed these additional complications, then correction of the severe physiological deficits before hysterectomy, if possible, could be life-saving [49,50]. (See "Peripartum hysterectomy for management of hemorrhage".)

In women with placenta accreta/increta/percreta or uterine rupture, early resort to hysterectomy may be the least morbid approach for controlling hemorrhage and may prevent deaths and morbidity caused by delays while ineffective fertility-preserving procedures are attempted. With improving prenatal diagnosis of placental attachment disorders, hysterectomy can often be anticipated and discussed with the patient before cesarean delivery. (See "Clinical features and diagnosis of the morbidly adherent placenta (placenta accreta, increta, and percreta)" and "Management of the morbidly adherent placenta (placenta accreta, increta, and percreta)".)

In contrast, uterine atony can usually be controlled by uterotonic drugs alone or in combination with fertility preserving procedures (uterine compression sutures, uterine artery/utero-ovarian artery ligation, arterial embolization, intrauterine balloon tamponade), as described above. Once the patient is resuscitated and the coagulopathy is reversed, hysterectomy may no longer be required to control hemorrhage. However, if fertility preserving procedures do not reduce the bleeding to a manageable level, then there is no choice but to proceed with hysterectomy.

Management of persistent bleeding after hysterectomy — Patients with continued severe hemorrhage after hysterectomy can enter a lethal downward spiral characterized by hypothermia, coagulopathy, and metabolic acidosis [49,51]. Criteria proposed for this "in extremis" state include pH <7.30, temperature <35°C, combined resuscitation and procedural time >90 minutes, nonmechanical bleeding, and transfusion requirement >10 units packed red blood cells (RBCs) [50].

To abort the cycle, the bleeding area is tightly packed and the skin is closed to prevent heat and moisture loss (either with large sutures or with towel clamps). Under most circumstances, the patient should remain in the operating room with continuous monitoring, while replacement of appropriate blood products and correction of physiologic derangements ("damage control") occurs. Once stable and safe for transfer, the patient may be transferred to the intensive care unit for ongoing management until definitive surgery can be performed. This approach halts the downward spiral and lessens the risk of abdominal compartment syndrome. Compartment syndrome is more difficult to define postpartum since postcesarean intra-abdominal pressure appears to be higher than in the general surgical population, especially in women with elevated body mass index and hypertensive disorders [52]. (See "Abdominal compartment syndrome in adults".)

One technique uses a sufficient number of gauze bandages (eg, Kerlix) tied end-to-end to pack the pelvis tightly and tamponade the hemorrhage. The free end of the gauze train is extracorporealized through the main incision. The peritoneum, muscle, and fascia are closed in the usual fashion, but with the gauze protruding from one end of the incision. The subcutaneous and cutaneous layers are left open and packed with additional gauze.

Different surgeons practice slight variations of this procedure ("umbrella pack") [53-61]. One variation is to fill a sterile plastic bag (eg, drawstring bag used to cover x-ray film) or cloth container with gauze and place it against the pelvic bleeders. The drawstrings are pulled through the vagina and attached to a weight, which provides traction so that the pack exerts pressure against the pelvic floor. A balloon tamponade device has also been used as a pelvic pressure pack after hysterectomy for PPH [62,63].

The need for ≥2 units packed RBCs per hour for three hours is a sign of significant ongoing bleeding and need for surgical intervention or arterial embolization by an interventional radiologist. Placement of a large

bore drainage catheter (such as a large Jackson-Pratt drain or a chest tube) in the pelvis at the time of temporary closure will allow early recognition of the need for emergency re-laparotomy.

Otherwise, the patient is returned to the operating room to undergo definitive surgical care in 48 hours. Packing should not be removed until coagulation defects have been corrected. If the packing has controlled bleeding, it generally is removed at this time. If it is removed too soon, bleeding will resume, whereas if it is removed too late, pelvic infection or abscess may ensue.

Under general anesthesia, the wound is opened and the gauze is removed with gentle traction. The pelvis is irrigated with saline to clear loose clots and other debris, but aggressive exploration of the pelvis is not performed if no pooling of blood is noted. The wound is then reapproximated in the usual manner. In one study, bleeding did not stop in 20 of 53 women despite abdominal packing; 6 required a second surgical intervention, 6 underwent pelvic artery embolization, and 8 had further intensive resuscitation and pharmacologic treatments [61].

ROLE OF INTERVENTIONAL RADIOLOGY

Arterial embolization — The main settings when embolization may be indicated are:

- At laparotomy, when persistent nonlife threatening deep pelvic bleeding occurs after repair of lacerations or hysterectomy and cannot be controlled by surgical ligation or ablation.

  Embolization is an option if the facility has a hybrid operating room, or an operating room that allows simultaneous surgery and embolization (an appropriately sensitive portable C-arm and carbon fiber table).

- After laparotomy, when persistent slow internal bleeding is suspected in a hemodynamically stable patient. The patient can be transferred to the interventional radiology suite for a diagnostic angiogram and embolization (if a bleeding source is seen).

  Hemodynamically unstable patients should be evaluated in the operating room, not the interventional radiology suite. If the facility has a hybrid operating room or an operating room that allows simultaneous surgery and embolization, performing uterine or hypogastric artery embolization in an operating room with the full surgical team in attendance is an option. Laparotomy is performed if the patient deteriorates during evaluation and embolization or the embolization fails.

- In patients with a morbidly adherent placenta. Embolization can reduce bleeding before and during hysterectomy or when conservative management (leaving the placenta in situ) is attempted. Direct arterial puncture of the internal iliac artery and embolization at cesarean delivery has been described in 16 cases of placenta accreta [64]. The procedure was successful in all of the cases and no complications (fever, buttock pain, acute limb ischemia) occurred. (See "Management of the morbidly adherent placenta (placenta accreta, increta, and percreta)", section on 'Balloon catheterization and arterial embolization'.)

Embolization after a failed uterine artery ligation is more difficult [65,66], although not impossible. In one study, arterial embolization was successful in 10 of 11 cases of failed surgical ligation therapy for PPH [67]. Thus, uterine artery embolization can be considered an option even after failed surgical ligation due to incomplete/ineffective occlusion. (See "Postpartum hemorrhage: Medical and minimally invasive management", section on 'Consider uterine or hypogastric artery embolization'.)

INFORMATION FOR PATIENTS — UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more

detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topic (see "Patient education: Postpartum hemorrhage (The Basics)")

SUMMARY AND RECOMMENDATIONS

- We suggest a vertical midline incision at laparotomy for treatment of postpartum hemorrhage (PPH), if the abdomen is not already open for cesarean delivery. (See 'Evaluation of the abdomen' above.)
- In hemodynamically unstable patients, temporizing maneuvers to reduce bleeding should be attempted prior to performing surgical procedures that take significant time to control hemorrhage. The option chosen depends on the urgency to control bleeding, the source of bleeding (intrauterine versus extrauterine), and the surgeon's expertise and preference:
  - Manual aortic compression (in highly urgent settings) (see 'Manual aortic compression' above)
  - Uterine tourniquet (see 'Uterine tourniquet' above)
  - Intrauterine balloon tamponade (see 'Intrauterine balloon tamponade' above)
  - Ligation of the uterine and utero-ovarian arteries (see 'Ligation of uterine and utero-ovarian arteries' above)
  - Pelvic pack (see 'Pelvic packing' above)
  - Clamp across utero-ovarian ligaments (note: will occlude fallopian tubes) (see 'Clamp across utero-ovarian ligaments' above)
  - Internal iliac artery ligation (procedure of last resort) (see 'Role of internal iliac artery ligation' above)
- Intraoperative blood salvage may be arranged before laparotomy or requested during laparotomy, but its use is investigational in the obstetrical setting. (See 'Role of intraoperative cell salvage' above.)
- Bleeding from a hysterotomy incision can generally be controlled by suture ligation. The angles of a transverse incision should be clearly visualized to ensure that they, and any retracted vessels, are completely ligated. If possible, the ipsilateral ureter should be identified before the bleeding is controlled and, once the hemorrhage has been controlled, the integrity of the ureter should be ensured. (See 'Myometrial lacerations' above.)
- Bilateral ligation of the uterine vessels (O'Leary stitch) is the preferred approach for controlling PPH from laceration of the uterine artery or branches of the utero-ovarian artery. If this does not control bleeding, the vessels of the utero-ovarian arcade are similarly ligated. (See 'Laceration of the uterine artery or utero-ovarian artery branches' above.)
- The interventions for reduction and control of bleeding due to atony are applied in rapid sequence until bleeding is controlled, which may be the result of the cumulative combined effect of multiple interventions. If uterine atony persists despite uterine massage and administration of uterotonic drugs and tranexamic acid, we suggest rapidly moving on to placement of uterine compression sutures, which are an effective method for reducing uterine blood loss related to atony. Manual compression of the uterus, insertion of an intrauterine balloon for tamponade, placement of a uterine tourniquet, and/or ligation of the uterine and utero-ovarian arteries can reduce ongoing heavy blood loss before attempting the procedure, and may obviate the need for the compression sutures. (See 'Atony' above.)

- Identification of an isolated bleeding point in the retroperitoneum is often impossible so it is rarely advisable to open the retroperitoneum or attempt dissection of an expanding retroperitoneal hematoma in a coagulopathic, hemodynamically unstable patient. Temporizing procedures can be used to stabilize the patient before beginning retroperitoneal surgery. (See 'Retroperitoneal bleeding' above.)

- Management of postpartum hemorrhage from placental abnormalities, including preoperative placement of balloon catheters by an interventional radiologist, are reviewed separately. (See "Placenta previa: Management" and "Management of the morbidly adherent placenta (placenta accreta, increta, and percreta)".)

- Early resort to hysterectomy is appropriate in women with severe bleeding due to diffuse placenta accreta/increta/percreta or a large uterine rupture. Hysterectomy is generally a last resort in patients with atony, but should not be delayed in those who have severe coagulopathy and require prompt control of uterine hemorrhage to prevent death. (See 'Role of hysterectomy' above.)

- Patients with persistent severe hemorrhage can enter a lethal downward spiral characterized by hypothermia, coagulopathy, and metabolic acidosis. To abort the cycle, the bleeding area is tightly packed and the wound dressed, but left open, and the patient is transferred to an intensive care unit for continuous monitoring, replacement of appropriate blood products, and correction of physiologic derangements. (See 'Management of persistent bleeding after hysterectomy' above.)

- The main settings when embolization may be indicated are (see 'Role of interventional radiology' above):

  - At laparotomy, when persistent nonlife threatening deep pelvic bleeding occurs after repair of lacerations or hysterectomy and cannot be controlled by surgical ligation or ablation. Embolization is an option if the facility has a hybrid operating room, or an operating room that allows simultaneous surgery and embolization (an appropriately sensitive portable C-arm and carbon fiber table).

  - After laparotomy, when persistent slow internal bleeding is suspected in a hemodynamically stable patient. The patient can be transferred to the interventional radiology suite for a diagnostic angiogram and embolization (if a bleeding source is seen).

    Hemodynamically unstable patients should be evaluated in the operating room, not the interventional radiology suite, unless the facility has a hybrid operating room or an operating room that allows simultaneous surgery and embolization. Laparotomy is performed if the patient deteriorates during evaluation and embolization or the embolization fails.

  - In patients with a morbidly adherent placenta.

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Topic 6712 Version 53.0

GRAPHICS

Potential interventions for treatment of postpartum hemorrhage

Pharmacologic interventions	
Drug	**Dosing**
Oxytocin	10 to 40 units in 500 to 1000 mL normal saline infused at a rate sufficient to control atony or 10 units IM
Tranexamic acid	1 g (10 mL of a 100 mg/mL solution) is infused over 10 to 20 minutes; if bleeding persists after 30 minutes, a second 1 g dose is administered
Ergots	Methylergonovine 0.2 mg IM every two to four hours or ergometrine 0.5 mg IV or IM or ergonovine 0.25 mg IM or IV every two hours
Carboprost	0.25 mg IM every 15 to 90 minutes up to eight doses or 500 mcg IM incrementally up to 3 mg or 0.5 mg intramyometrial
Misoprostol	800 to 1000 mcg rectally
Dinoprostone	20 mg vaginally or rectally every two hours
Recombinant human Factor VIIa	50 to 100 mcg/kg every two hours
Surgical interventions	
Repair lacerations	
Curettage	
Uterine compression suture (eg, B-Lynch suture)	
Uterine artery ligation	
Utero-ovarian artery ligation or cross clamp	
Pelvic packing	
Uterine tourniquet	
Focal myometrial excision	
Use of fibrin glues and patches to cover areas of oozing and promote clotting	
Placement of figure 8 sutures or other hemostatic sutures directly into the placental bed	
Internal iliac artery (hypogastric artery) ligation	
Aortic compression	
Hysterectomy, supracervical	
Hysterectomy, total	
Interventional radiology	
Selective arterial embolization	
Intermittent aortic balloon occlusion	
Common iliac artery balloon occlusion	
Blood bank	
Packed red blood cells	
Platelets	
Fresh frozen plasma	
Cryoprecipitate	

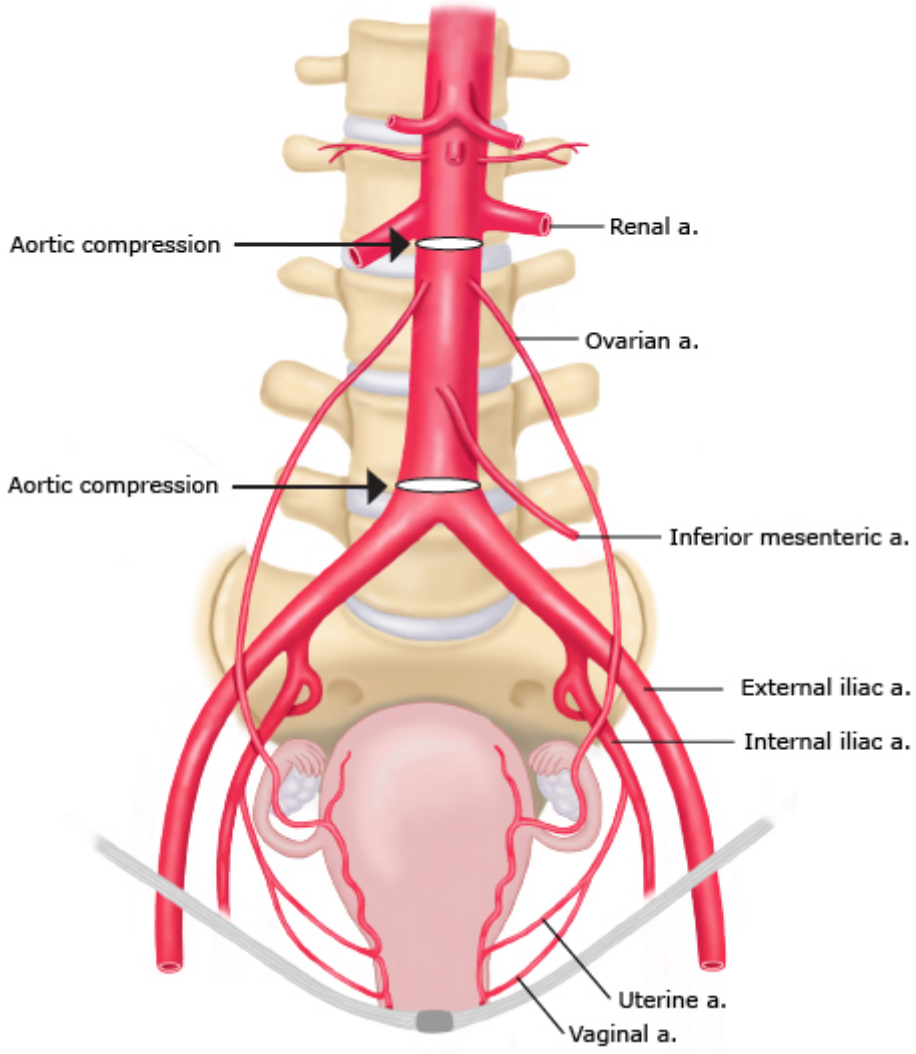
Nonsurgical interventions
Uterine massage
Intravenous fluids
Tamponade
Intrauterine tamponade with an intrauterine balloon or alternative device (eg, bladder catheter bulb, Sengstaken-Blakemore tube)
Uterine packing (eg, 4 inch gauge packing)
Consultations
General surgery
Trauma surgery
Anesthesia team
Interventional radiology
Gynecologic oncology
Urology

IV: intravenous; IM: intramuscular; mcg: micrograms; kg: kilogram.

Data from: Dahlke JD, Mendoz-Figueroa H, Maggio L, et al. Prevention and management of postpartum hemorrhage: a comparison of 4 national guidelines. Am J Obstet Gynecol 2015; 213.e1.

Graphic 73412 Version 6.0

Potential sites for manual aortic compression at laparotomy for control of postpartum hemorrhage.

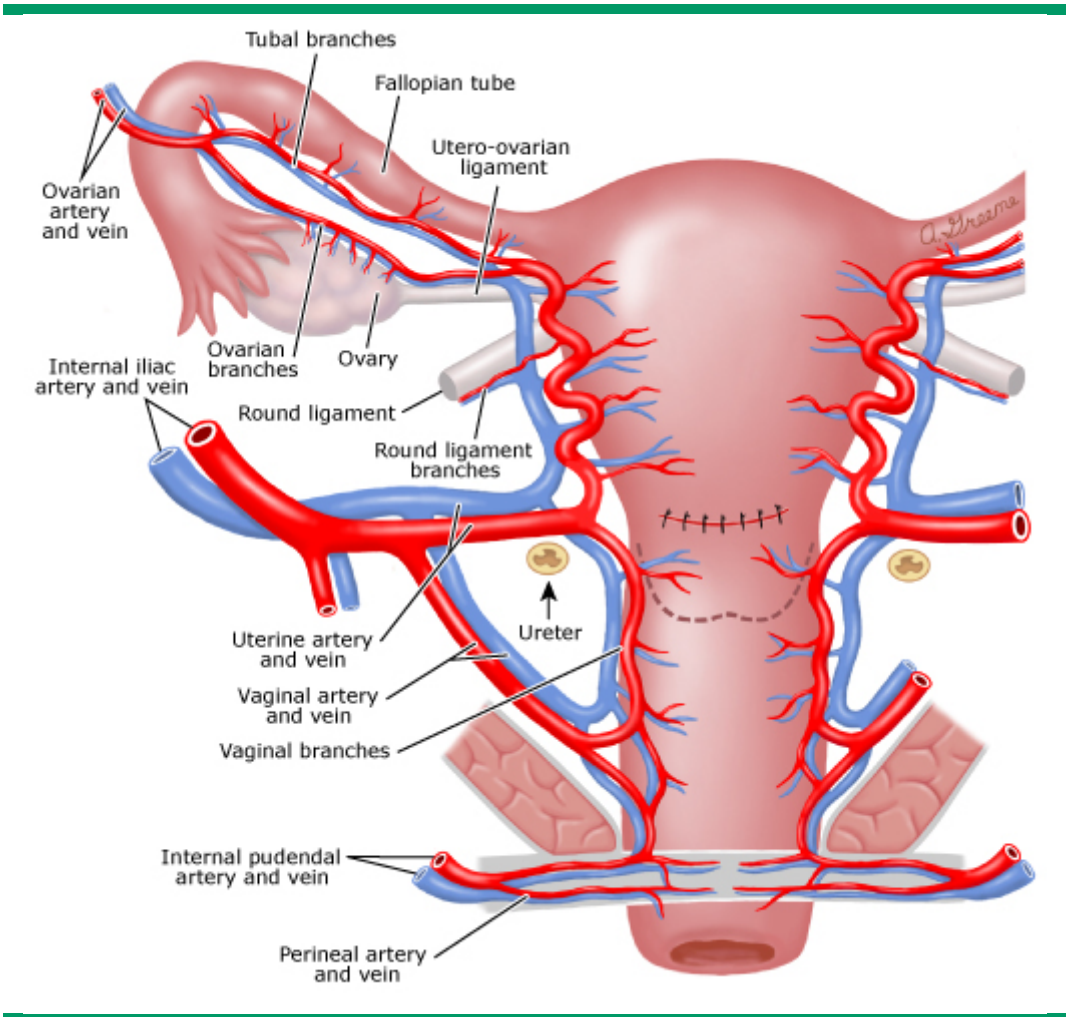


If there is an imminent threat of exsanguination (ie, within a few minutes), the surgeon should compress the aorta against the vertebrae a few centimeters superior to the sacral promontory; the bifurcation into the common iliac arteries is just distal to this point. Alternatively, the aorta can be compressed just below the renal arteries, which will minimize collateral flow to the uterus from the ovarian and inferior mesenteric arteries. Compression at either site will slow the volume of bleeding and will afford a better opportunity for finding and controlling the source of hemorrhage. Compression just above the bifurcation may be easier to accomplish, but is less effective than below the renal arteries because of the extensive collateral blood supply to the uterus.

An intraaortic balloon catheter is another option. The balloon is positioned below the renal arteries and above the ovarian and inferior mesenteric arteries and then inflated, which should lead to a substantial reduction in uterine blood flow. The balloon must be deflated intermittently to prevent ischemic limb and colon complications.

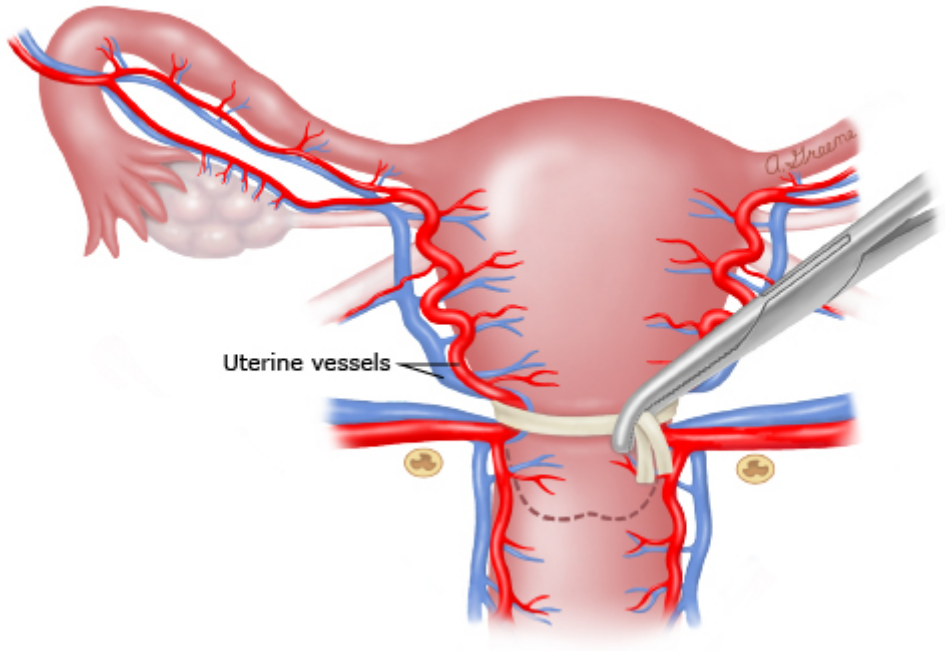
Graphic 115271 Version 1.0

Uterine vessels, ureter, uterus after cesarean delivery



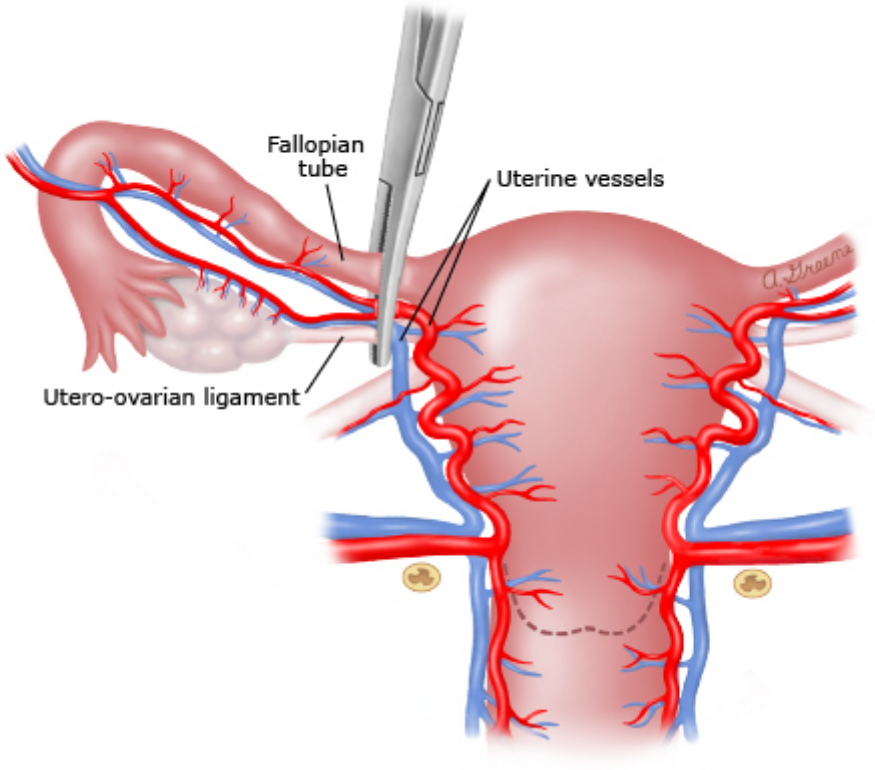
Graphic 99540 Version 4.0

Placement of uterine tourniquet for managing uterine hemorrhage



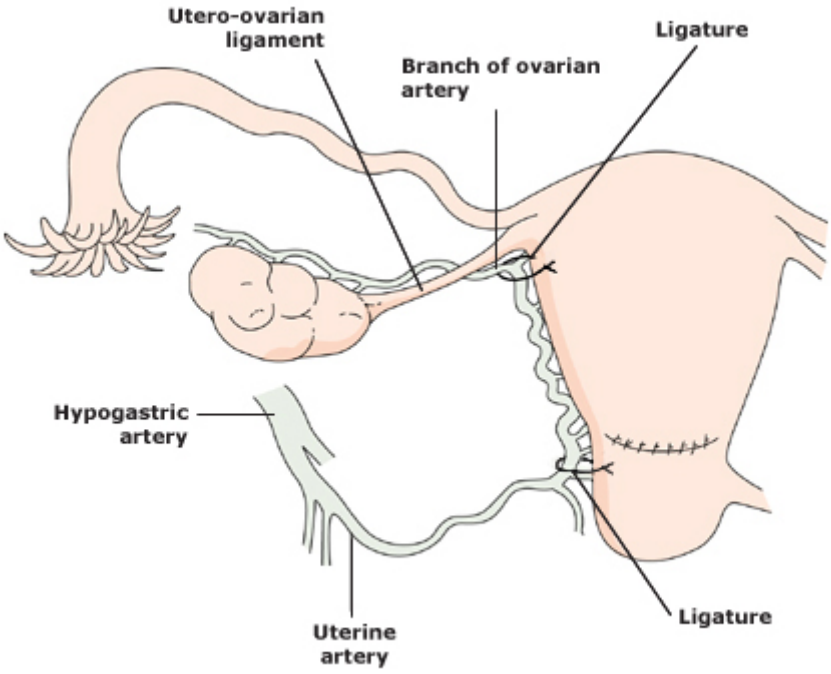
Graphic 113917 Version 2.0

Clamp across the utero-ovarian vessels and ligament to reduce uterine bleeding



Graphic 113918 Version 2.0

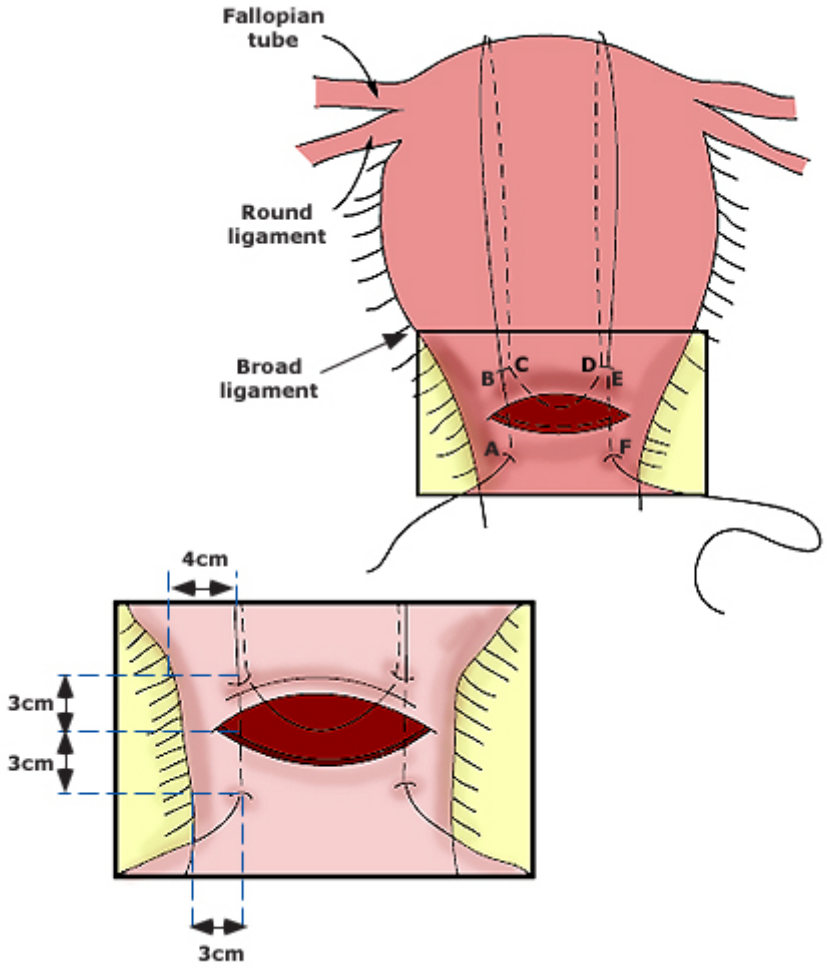
Uterine artery ligation



Sutures are placed to ligate the ascending uterine artery and the anastomotic branch of the ovarian artery. The procedure should be performed on each side.

Graphic 77881 Version 1.0

Anterior uterine wall with B-Lynch suture in place and an enlarged drawing (box) of lower uterine segment with B-Lynch suture in place

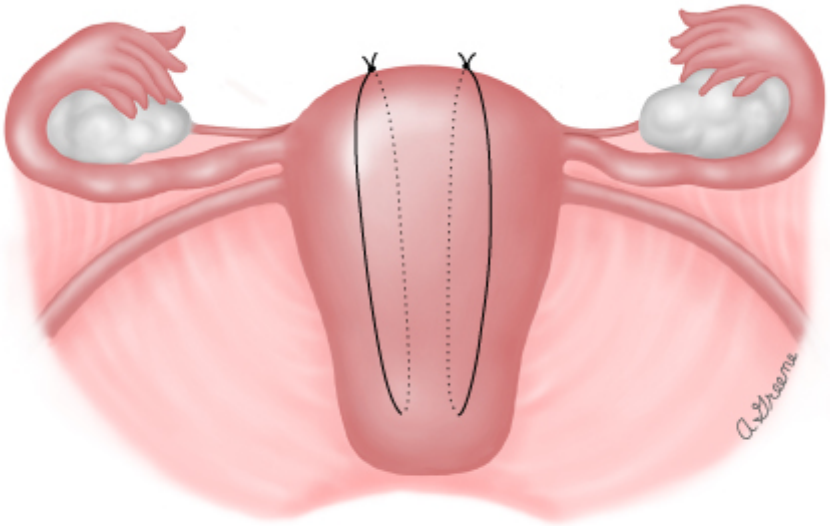


A large Mayo needle with #2 chromic catgut is used to enter and exit the uterine cavity at A and B. The suture is looped over the fundus and then reenters the uterine cavity posteriorly at C, which is directly below B. The suture should be pulled very tight at this point. It then enters the posterior wall of the uterine cavity at D, is looped back over the fundus, and anchored by entering the anterior lateral lower uterine segment at E and crossing through the uterine cavity to exit at F. The free ends at A and F are tied down securely to compress the uterus.

Adapted from: Ferguson JE, Bourgeois JF, Underwood PB. B-LYNCH SUTURE FOR POSTPARTUM HEMORRHAGE. Obstetrics & Gynecology 2000; 95(Supp 6):1020.

Graphic 71907 Version 2.0

Hayman stitch

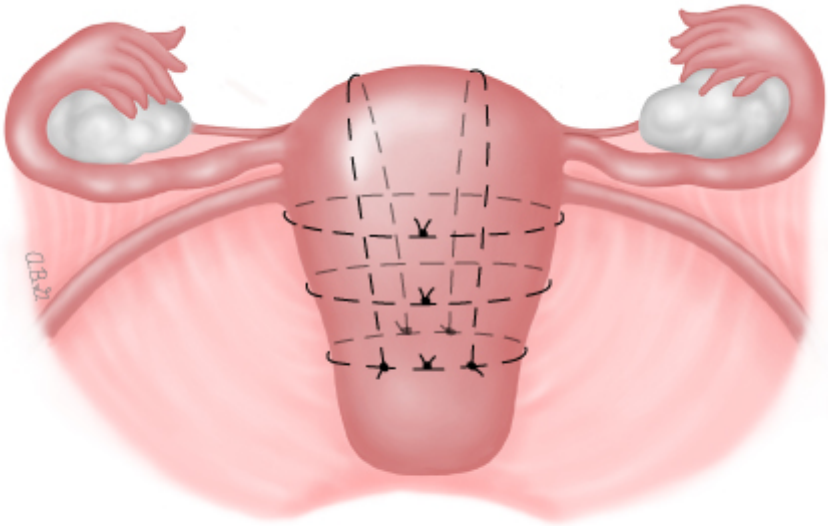


Hayman described a modification of the B-Lynch suture that is performed without a hysterotomy. Two to four vertical compression sutures are placed, as needed, but in contrast to the B-Lynch technique, these sutures pass directly from the anterior uterine wall to the posterior uterine wall. A transverse cervicoisthmic suture can also be placed if needed to control bleeding from the lower uterine segment.

Hayman, RG, Arulkumaran, S, Steer, PJ. Uterine compression sutures: surgical management of postpartum hemorrhage. Obstet Gynecol 2002; 99:502.

Graphic 59142 Version 3.0

Pereira stitch

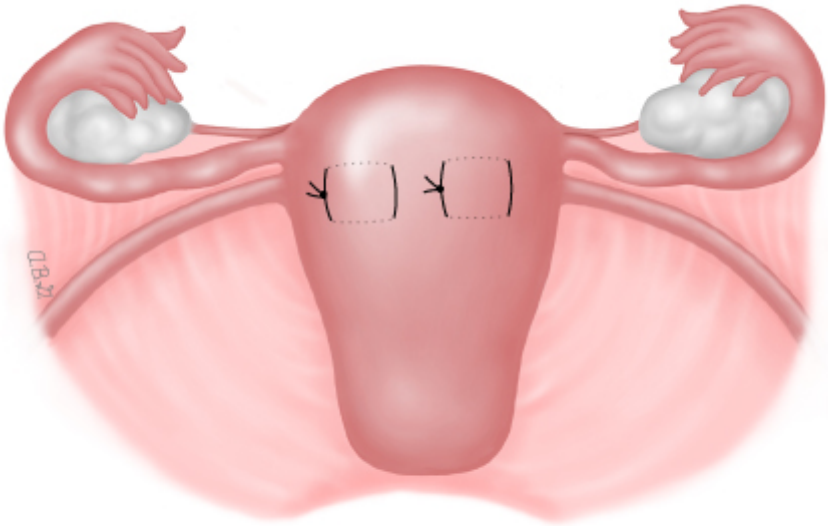


Pereira described a technique in which a series of transverse and longitudinal sutures of a delayed absorbable multifilament suture are placed around the uterus via a series of bites into the submucosal myometrium. Two or three rows of these sutures are placed in each direction to completely envelope and compress the uterus, similar to the way one might truss a stuffed roast. When the transverse sutures are brought through the broad ligament, care should be taken to avoid damaging blood vessels, ureters, and fallopian tubes. The longitudinal sutures begin and end at the last transverse suture nearest the cervix, and do not enter the uterine cavity. The myometrium should be manually compressed prior to tying down the sutures to facilitate maximal compression.

Pereira, A, Nunes, F, Pedroso, S, et al. Compressive uterine sutures to treat postpartum bleeding secondary to uterine atony. Obstet Gynecol 2005; 106:569.

Graphic 64085 Version 2.0

Cho stitch



Cho described a technique in which a straight number 7 or 8 needle with #1 chromic catgut is used to place sutures in a small rectangular array to compress the anterior and posterior uterine walls against one another at sites of heavy bleeding. The through and through sutures extend from the serosa of the anterior wall to the serosa of the posterior wall. After creating a square, the ends are tied down as tight as possible to compress the myometrium. Two to five squares/rectangles are made, as needed.

Cho, JH, Jun, HS, Lee, CN. Hemostatic suturing technique for uterine bleeding during cesarean delivery. Obstet Gynecol 2000; 96:129.

Graphic 58733 Version 2.0

Contributor Disclosures

Michael A Belfort, MBBCH, MD, PhD, FRCSC, FRCOG Patent Holder: Clinical Innovations [Postpartum hemorrhage (Balloon tamponade system for control of postpartum hemorrhage)]. **Charles J Lockwood, MD, MHCM** Nothing to disclose **Vanessa A Barss, MD, FACOG** Nothing to disclose

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