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Abnormal Placentation: Evidence-Based Diagnosis and Management of Placenta Previa, Placenta Accreta, and Vasa Previa

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Placenta previa, placenta accreta, and vasa previa cause significant maternal and perinatal morbidity and mortality. With the increasing incidence of both cesarean delivery and pregnancies using assisted reproductive technology, these 3 conditions are becoming more common. Advances in grayscale and Doppler ultrasound have facilitated prenatal diagnosis of abnormal placentation to allow the development of multidisciplinary management plans to achieve the best outcomes for mother and baby. We present a comprehensive review of the literature on abnormal placentation including an evidence-based approach to diagnosis and management.

Targeted Audience: Obstetricians & Gynecologists, Family Physicians.

Learning Objectives: After completing this CME activity, physicians should be better able to: assess risk factors associated with placenta previa, placenta accreta, and vasa previa; evaluate sonographic characteristics of placenta previa, placenta accreta, and vasa previa; formulate antepartum management plans and delivery plans for patients with placenta previa, placenta accreta, and vasa previa; implement preoperative planning and surgical techniques used in management of placenta previa, placenta accreta, and vasa previa; and categorize the risks and benefits associated with conservative management of placenta accreta.

Placenta previa, placenta accreta, and vasa previa cause significant maternal and perinatal mortality and morbidity. Antepartum bleeding secondary to placenta previa is responsible for a perinatal mortality rate of 2.3%, whereas undiagnosed vasa previa has a fetal mortality rate of approximately 60%.[1,2] In the United States, the rate of peripartum hysterectomy for placenta accreta increased by 20% between 1994 and 2007, whereas in Ireland, placenta accreta as an indication for peripartum hysterectomy increased over a 40-year period (1966–2005) from 5.4% to 46.5%.[3,4] An average blood loss of 3 to 5 L can be expected at the time of delivery in the most severe cases of placenta accreta and maternal mortality has been reported in up to 7% of cases.[5,6] Advances in ultrasound have facilitated the prenatal diagnosis of these conditions to allow the development of multidisciplinary management plans to achieve the best outcomes for the mother and her baby. The purpose of this review was to provide an evidence-based approach to the diagnosis and management of these 3 major causes of perinatal and maternal morbidity. This review will present the risk factors, sonographic characteristics, antepartum management, and delivery planning associated with placenta previa, placenta accreta, and vasa previa.

All faculty and staff in a position to control the content of this CME activity and their spouses/life partners (if any) have disclosed that they have no financial relationships with, or financial interests in, any commercial organizations related to this CME activity.

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PLACENTA PREVIA

Placenta previa occurs when the placenta covers the cervix either completely or partially. When the cervix dilates or the lower uterine segment (LUS) effaces,

bleeding can result because of placental separation and the proximity of the placenta to the cervix. Transvaginal ultrasound (TVUS) allows localization of the placenta in relation to the internal cervical os with great precision. Complete placenta previa entirely covers the internal os, whereas marginal placenta previa has the inferior placental edge adjacent to the internal cervical os or within 2 cm of the internal cervical os.[7] Partial placenta previa has the inferior placental margin partially overlapping the internal cervical os.[8] When the placenta is greater than 2 cm from the cervix, there is no increased risk of bleeding.[8,9]

Except for cases of complete central previa in the second trimester, definitive diagnosis of placenta previa should be avoided in asymptomatic patients before the third trimester, as many cases identified early in pregnancy will resolve as pregnancy advances. First-trimester bleeding should not be attributed to a previa because this diagnosis is not appropriate for describing placental location this early in gestation. The term *low-lying* placenta provides little information about clinical significance, although it may be an appropriate term in the first and second trimesters. However, it is preferable for sonologists to precisely describe the relationship of the placenta to the cervix or the actual distance between the placental edge and the internal cervical os. Ninety percent of placentas identified as low-lying in early pregnancy will resolve by the third trimester.[10] This phenomenon is thought to be due to trophotropism where the placenta grows toward a better blood supply at the fundus, leaving distal portions of the placenta closer to the relatively poor blood supply of the LUS to regress and atrophy. Differential elongation of the LUS may further increase the distance between the lower placental edge and the cervix without trophotropism.

Incidence and Risk Factors

Placenta previa affects 1 of every 200 pregnancies at term.[11] Faiz and Ananth[12] performed a meta-analysis of 58 studies on placenta previa between 1966 and 2000 determining an overall prevalence rate of 4.0 per 1000 births. The underlying cause of placenta previa is unknown. However, there is a clear association between placental implantation in the LUS and prior endometrial damage and uterine scarring that result from curettage, surgical insult, prior placenta previa, and multiple prior pregnancies.[8] There is an increasing incidence of placenta previa related to the increasing rate of cesarean delivery in developed countries.[13] A single prior cesarean delivery almost doubles the baseline risk for development of placenta previa in a subsequent pregnancy from 0.38% to 0.63% and the incidence of placenta previa rises even further with more than 2 prior cesarean deliveries (Table 1).[13–16] Advanced maternal age is associated with a 2% incidence of placenta previa after age 35 and that risk increases to 5% after age 40.[9,17,18] Multiparity, prior spontaneous and induced abortions, and smoking are all associated with higher risks of previa (Tables 1).[17,19–21] Iyasu et al[9] reported that Asian race was associated with twice the risk of placenta previa compared with other ethnicities. Obed and Adewole[22] reported a 2.5-fold increased risk of placenta previa in women with a history of first-trimester threatened abortion. For unknown reasons, pregnancies complicated by placenta previa have been reported to be associated with higher rates of fetal anomalies,[1] neurodevelopmental delay,[23] and sudden infant death syndrome.[24]

Antepartum Hemorrhage

In cases of placenta previa, bleeding may occur before labor as a result of development of LUS and effacement of cervix with advancing gestation as well as uterine contractions. Although evidence is lacking, antepartum bleeding has also been attributed to intercourse and injudicious vaginal examination. Significant bleeding occurs once true labor begins as the cervix dilates and the placenta separates from underlying decidua. The classic history is that of painless third-trimester bleeding. Several small ''herald bleeds'' may precede major hemorrhage with no bleeding until the onset of labor in 10% of cases.[25] Ghi et al[26] noted that a transvaginal cervical length of 31 mm or less was associated with an almost 50% risk of hemorrhage and emergency cesarean delivery before 34 weeks in patients with complete placenta previa. Likewise, Stafford et al[27] reported that a third-trimester cervical

TABLE 1
Risk Factors for Placenta Previa*

	OR (95% CI)
Prior cesarean deliveries	
1	4.5 (3.6–5.5)
2	7.4 (7.1–7.7)
3	6.5 (3.6–11.6)
4	44.9 (13.5–149.5)
Induced or spontaneous abortions	
1	1.6 (1.3–1.8)
2	2.3 (1.8–3.0)
3	3.7 (2.7–5.2)
Parity	
1	1.9 (1.5–2.5)
2	2.2 (1.7–3.0)
3	2.6 (1.8–3.8)

**Am J Obstet Gynecol* (1997;177:1071–1078), *Am J Obstet Gynecol* (1993;166:641–645), and *Obstet Gynecol* (1996;88:511–516).
CI indicates confidence interval; OR, odds ratio.

length of 30 mm or less was associated with an increased risk for hemorrhage, uterine activity, and preterm birth in pregnancies with placenta previa. Zaitoun et al[28] found that cervical length of 30 mm or less, and increased lower placental edge thickness measurements accurately predicted the risk of antepartum hemorrhage and emergency cesarean delivery in patients with complete placenta previa. Saitoh et al[29] found the risk of sudden, severe hemorrhage was 10 times higher in women with complete placenta previa with an echo-free space in the placental edge overlying the internal os compared to women with other types of placenta previa. In contrast, Hasegawa et al[30] reported that no ultrasound finding, including cervical length, could predict bleeding episodes or the need for an eventual emergency cesarean delivery.

All women with painless vaginal bleeding after 20 weeks' gestation should be assumed to have placenta previa until proven otherwise. Digital or speculum examination should not be performed until placenta previa has been excluded by ultrasound. The ''double-setup'' examination was common before the ready availability of ultrasound and is still performed in developing countries. The patient with late pregnancy bleeding is taken to the operating room and preparations are made for cesarean delivery. A careful vaginal examination is performed beginning in the vaginal fornices while avoiding placement of the examining fingers directly into the cervix. A cesarean delivery is then performed if placenta previa is detected or hemorrhage ensues.

Prenatal Diagnosis

In all patients, TVUS should be performed to carefully evaluate the relationship of placenta to the cervix. Visualizing a fundal placenta on transabdominal ultrasound does not remove the need to perform TVUS as the placenta can extend from fundus to the cervix or be associated with a succenturiate lobe. Concerns for the potential of TVUS to provoke bleeding are unfounded and several studies confirm the safety of a careful TVUS approach.[31] The technique for TVUS of placenta previa involves placing the transducer within the vagina about 2 cm from the anterior lip of the cervix with the angle between the transducer and cervical canal at 35 degrees to prevent entry of the probe into the cervix.[8] Translabial imaging using the transabdominal ultrasound probe can also produce excellent results with better visualization of relationship between cervix and placenta than conventional transabdominal scanning.[32]

Transabdominal ultrasound overdiagnoses low-lying placenta especially when the bladder is empty and is associated with incorrect diagnoses approximately 25% of the time.[8,33] Transvaginal ultrasound findings in the first and second trimesters may not correlate with placental position at term and up to 10 times more women are found to have ''placenta previa'' in the first or second trimester than at delivery.[34] The positive predictive value for placenta previa at delivery increases the later in gestation that previa is detected sonographically.[35] It is less likely that placenta previa will persist at delivery earlier in pregnancy that the diagnosis is made as 12% and 34% of previas diagnosed at 15 to 19 and 20 to 23 weeks' gestation, respectively, persisted until delivery in a retrospective cohort at Parkland Hospital.[35] Taipale et al[36] reported that screening for placenta previa at 18 to 23 weeks' gestation was more effective than screening at 12 to 16 weeks' gestation because the prevalence of previa had decreased from 4% to 1% by the later interval. Lauria et al[37] found that placental overlap of the cervical os by 10 mm before 24 weeks' gestation was associated with a 38% risk of persistence until delivery, which increased to 57% with any degree of previa after 24 weeks' gestation. The likelihood of persistence of placenta previa to term is also related to thickness of placental edge. Ghourab[38] found that persistence was more likely in placenta with a thin edge ($\leq$1 cm and/or angle of placental edge < 45 degrees) rather than a thick edge (>1 cm and/or angle of placental edge >45 degrees).

Follow-up ultrasound should be performed at 32 weeks' gestation to confirm placental position, and a final study may be performed at 36 weeks' gestation before deciding on route of delivery in cases in which a marginal or partial previa persists at 32 weeks. Oyelese[39] demonstrated that the likelihood of persistence of complete previa and marginal previa at delivery was significantly higher in patients with a prior cesarean delivery. At 24 to 27 weeks, patients with a marginal previa and no prior cesarean had a 12% chance of persistence at delivery compared with 40% for patients with a prior cesarean delivery. Similarly, for patients with a complete previa and no history of prior cesarean, at 24 to 27 weeks, the likelihood of persistence at delivery was 56% compared with 84% in those with a prior cesarean delivery.

Antepartum Management

Delivery is appropriate for definite placenta previa at or beyond 36 weeks with bleeding. Delivery should take place if bleeding is excessive or there are concerns about fetal condition after viability. In all other cases, conservative management has been shown to

be safe with prolongation of pregnancy by an average of 4 weeks after the initial bleed, although significant prolongation of pregnancy is less likely closer to 36 weeks' gestation.[40] Betamethasone to enhance lung maturity should be administered to patients less than 34 weeks' gestation.

Use of tocolytics is controversial in the setting of hemorrhage. Aggressive expectant management of symptomatic placenta previa with long-term tocolysis was proposed in the early 1980s, with anecdotal reports of successful prolongation of pregnancy.[41,42] One prospective randomized trial and 2 retrospective analyses report significant prolongation of pregnancy without increased morbidity or mortality in women with symptomatic placenta previa using ritodrine for tocolysis, although no reduction in the frequency or severity of bleeding was noted.[43–45] However, β-mimetics, which were used for tocolysis in these 3 studies, are associated with significant adverse effects especially maternal tachycardia, which can mask the physiologic response to severe volume depletion from hemorrhage. As such, further research is needed, and the risks and benefits of tocolysis should be considered before recommending their use in symptomatic patients with placenta previa.

After initial presentation, patients should remain in the hospital until free from bleeding for 48 hours, and some of these patients may be considered for outpatient management, which seems to be a safe approach.[46] Criteria for home management include a patient who is asymptomatic with no bleeding or abdominal pain, able to remain at home with limited activity, has adequate support at home and access to telephone, and has adequate access to transport to a nearby hospital if bleeding recurs. The likelihood of recurrent bleeding after an initial episode is greater than 60% and a second significant bleeding episode results in readmission until delivery because these patients are at a higher risk for earlier delivery and have lower-birthweight babies.[46,47] Cervical length surveillance in patients with placenta previa may be appropriate to identify patients at increased risk for hemorrhage.

There is no conclusive evidence to support bed rest, reduced activity, or avoidance of intercourse to reduce the risk of antepartum hemorrhage. Cervical cerclage in cases of placenta previa was evaluated in 2 small prospective studies without clear benefit and is not recommended.[48,49]

Delivery Considerations

Some investigators contend that all women whose placenta lies within 2 cm of the cervix by TVUS in the third trimester should be delivered by cesarean delivery because more than 90% of women with placental edge-to-internal os distance less than 2 cm required cesarean delivery, whereas 63% of women with a distance greater than 2 cm had a vaginal delivery.[50,51] These findings may be biased as the physicians in these studies were not blinded to the ultrasound examinations.

If the distance between the lower edge of the placenta and the internal cervical os is less than 10 mm, the risk of bleeding before labor is 29%, and 75% of these women will require cesarean delivery due to bleeding in labor.[52] If the placenta-to-os distance is greater than 10 mm, the risk of antepartum hemorrhage is only 3%, and some suggest that these women may be offered a trial of labor because 69% of women with a placental edge to internal os distance of 11 to 20 mm delivered vaginally without an increased risk of hemorrhage.[52] Bronsteen et al[53] found a vaginal delivery rate of 76.5% among women with placenta-to-os distances of 1 to 2 cm and 27.3% among women whose placenta was within 1 cm of the internal cervical os. However, women with a placenta edge within 4 cm of the internal os have an increased risk of postpartum hemorrhage regardless of mode of delivery because of the weak contractile ability of the LUS.[39]

The Royal College of Obstetricians and Gynaecologists in the United Kingdom recommends that cesarean delivery for placenta previa be performed by the most experienced team available owing to the substantial risk of intraoperative hemorrhage.[54] However, it is common practice in the United States for many of these patients, especially those with uncomplicated previas, to be delivered of their infants by resident physicians and junior attending physicians.

A low-transverse (Kerr) incision is appropriate. For anterior placenta previa, operators should clamp the umbilical cord immediately after delivery of the infant to prevent excessive blood loss caused by disruption of placenta on entry, and a classic, vertical incision may be required in such cases if there is malpresentation or to avoid a complete central previa.[55] Because inhaled anesthetics cause uterine relaxation, regional anesthesia is associated with lower operative blood loss and less need for transfusion than general anesthesia.[56] Postpartum hemorrhage may occur from the placental implantation site due to atony and may require combination pharmacological agents. The B-Lynch suture, local suturing of the placenta bed, or intrauterine balloon tamponade may also be needed to control bleeding.[57–59] Hysterectomy may be required in cases of refractory hemorrhage. Al-Harbi et al[60] and Ge et al[61] reported the safety and effectiveness of uterine packing

with sterile gauze in control of intractable hemorrhage during cesarean delivery for placenta previa especially in developing countries. Law et al[62] described the topical application of hemostatic gel to provide effective hemostatic control in the LUS at the time of laparotomy for postpartum hemorrhage after cesarean delivery for placenta previa.

Elective delivery should be performed in women with known placenta previa before significant bleeding has occurred. It is reasonable to plan delivery at or just after 36 weeks' gestation because there is little fetal advantage after this time compared to the risk of sudden catastrophic bleeding. Amniocentesis has historically been performed to confirm fetal lung maturity (FLM), but the risk of hemorrhage with delayed delivery outweighs the risk of fetal lung immaturity at this gestational age. A recent decision analysis demonstrated that steroid administration at 35 weeks 5 days followed by cesarean delivery at 36 weeks without amniocentesis optimized maternal and neonatal outcomes for women with placenta previa.[63]

PLACENTA ACCRETA

Placenta accreta involves trophoblastic invasion beyond the normal boundary established by the spongiosus (Nitabuch) layer within the decidua basalis with attachment of chorionic villi to the myometrium. Placenta increta results when invasion of chorionic villi extends into the myometrium. Placenta percreta refers to invasion of chorionic villi through the myometrium beyond the uterine serosa involving the bladder and/or other pelvic organs. In all cases of placental attachment disorders, Miller et al[64] found 75% to be placenta accreta, 18% increta, and 7% percreta. Hysterectomy is usually required to control or prevent life-threatening hemorrhage, and there is a frequent need for transfusion of blood products. Placenta accreta accounts for 33% to 50% of all emergency peripartum hysterectomies, and at tertiary centers, antenatal diagnosis has been shown to reduce blood loss and other operative complications.[65–69] Optimal management of women with placenta accreta requires recognition of clinical risk factors, accurate prenatal diagnosis, comprehensive maternal counseling, coordinated multidisciplinary planning, and meticulous surgical technique to ensure safety for mother and fetus at the time of delivery.[70]

Incidence and Risk Factors

In 1985, the incidence of placenta accreta was 0.8 per 1000 deliveries.[71] More than 20 years later, the incidence has risen to 3 per 1000 deliveries.[4] Wu et al[72] reported a 10-fold rise in the incidence of placenta accreta since the 1970s, which parallels the increasing rate of cesarean deliveries in the United States, which accounted for 32.8% of all births in 2008.[73] The strongest association exists with placenta previa and prior uterine surgery.[74,75] Additional risk factors for placenta accreta include advanced maternal age, smoking, multiparity, short cesarean-to-conception interval, prior uterine curettage or surgery, uterine irradiation, and endometrial ablation (Table 2).[72,76,77] Blanc et al[78] suggest that uterine-sparing surgical management of intractable postpartum hemorrhage involving triple uterine artery ligation and hemostatic placental bed suturing may be associated with a risk of abnormal placentation and other adverse obstetric outcomes in a subsequent pregnancy. The risk of placenta accreta in the presence of placenta previa increases with the number of prior cesarean deliveries, rising from 11% after 1 prior cesarean to 40% after 2 prior cesarean deliveries, 61% after 3 prior cesarean deliveries, and 67% after 4 or more prior cesarean deliveries (Table 2).[71] In patients without a placenta previa, the risk of placenta accreta is less than 1% after 5 cesarean deliveries and approaches 5% with greater than 6 prior cesarean deliveries.[75]

Esh-Broder et al[79] recently observed that the risk of placenta accreta is significantly higher in in vitro fertilization (IVF) pregnancies (0.167%) compared with spontaneous pregnancies (0.012%) possibly because of the differences in the endometrial environment or changes in the endometrium from IVF treatment protocols.

Pregnancies in women with a history of endometrial ablation carry a significant risk of poor obstetric outcome including an 18% rate of placenta accreta.

TABLE 2
Risk Factors for Placenta Accreta*

Placenta previa
Prior uterine curettage
Advanced maternal age
Smoking
Multiparity
Short cesarean-to-conception interval
Advanced reproductive technology/IVF
Uterine irradiation
Endometrial ablation
Prior uterine surgery

Prior Cesarean Deliveries	Risk of Placenta Accreta
1	11%
2	40%
3	61%
4	67%

Obstet Gynecol (1985;66:89–92).

Hare and Olah[80] reported a 32.3% rate of placenta accreta in a series of 70 pregnancies after various endometrial ablation treatments and 71% of these pregnancies after endometrial ablation underwent cesarean delivery. Patni et al[81] recommend that all pregnancies after endometrial ablation should be assumed to have abnormal placentation until proven otherwise and preparations for delivery should be made accordingly. Hamar et al[82] report a case of preterm premature rupture of membranes and placenta increta in a pregnancy after saline balloon thermal ablation for dysmenorrhea with complete absence of established sonographic markers for abnormal placentation. The patient had several ultrasound evaluations by the maternal-fetal medicine service both before and after rupture of membranes using grayscale, color Doppler, and power Doppler imaging, which demonstrated a normal anterior placenta. These investigators hypothesized that placentation after endometrial ablation may differ from placentation in classic placenta accreta as the placenta is globally adherent to an abnormal uterine lining which limits focal placental invasion thus preventing development of classic ultrasound findings described for placenta accreta.[83]

Pathophysiology

Two possible mechanisms for the pathophysiology and formation of placenta accreta have been proposed and it is likely that both play a role. In cases of abnormal decidualization, a localized defect in the natural decidual barrier, due to cesarean delivery or myomectomy scar, uterine curettage, pelvic radiation, or localization of placenta to an area deficient of decidua around the cervical os, allows the trophoblast to break through the decidua and invade the uterine wall.[84] The excessive trophoblastic invasion of placenta accreta may be associated with overexpression of certain CD44 receptors also seen in highly metastatic choriocarcinomas, changes in trophoblast growth factors and angiogenesis factors, altered adrenomullin gene expression, and mitochondrial DNA mutations.[85–88]

Complications associated with placenta accreta at the time of delivery include damage to bladder, bowel, ureters, and neurovascular structures in the retroperitoneum and lateral pelvic sidewalls from placental implantation and removal.[89] Amniotic fluid embolism, postoperative thromboembolism, infection, multisystem organ failure, and maternal death have all been reported in association with placenta accreta.[90,91] The incidence of maternal death may be as high as 6% to 7% in some case series.[6] Complications from transfusion of large volumes of crystalloid, blood products, and other volume expanders may also occur including dilutional coagulopathy, consumptive coagulopathy, immediate transfusion reactions, transfusion-associated lung injury, acute respiratory distress syndrome, and electrolyte abnormalities.[92] Rosen[93] reported that admission to the intensive care unit was required for 51.6% of women with placenta accreta, with 29% of these patients having intraoperative complications, whereas 40% had postoperative complications. Although very rare, uterine rupture secondary to placenta percreta has also been reported.[94,95]

Prenatal Diagnosis

The diagnosis of placenta accreta can usually be made by ultrasound (Table 3). It is important to make the diagnosis before delivery because intraoperative hemorrhage can be massive and placenta accreta is the most common indication for emergency peripartum hysterectomy.[96] Comstock[97] reported a sensitivity of 80% and a specificity of 95% using only the presence of placental lacunae to make the diagnosis. Chou et al[98] observed that color-flow and power Doppler sonography may facilitate the diagnosis with 82% sensitivity and 97% specificity. Dwyer et al[99] found no statistical difference in sensitivity or specificity between ultrasound and magnetic resonance imaging (MRI), as sonography demonstrated 93% sensitivity and 71% specificity, whereas MRI showed 80% sensitivity and 65% specificity.

The normal placenta has a homogenous appearance on ultrasound with a hypoechoic boundary between the placenta and the bladder representing myometrium and the normal retroplacental myometrial vasculature. The loss of this sonolucent retroplacental zone is associated with 57% sensitivity and 52% specificity for placenta accreta.[100] The presence of multiple vascular lacunae within the placenta has 79% sensitivity and 92% positive predictive value for placenta accreta.[100] These lacunae frequently demonstrate low-resistance turbulent flow with high peak systolic velocities.[101] Sonographic findings may also include vascular or placental projections bridging the uterine-placenta margin, the myometrial-bladder interface, or penetrating

TABLE 3
Ultrasound Findings of the Placenta Accreta

Placental lacunae with low-resistance turbulent flow and high peak systolic velocities
Loss of sonolucent retroplacental zone
Vascular or placental projections into the myometrium, bladder, or uterine serosa
Retroplacental myometrial thickness <1 mm with placenta lacunae

the uterine serosa. A retroplacental myometrial thickness of less than 1 mm in the presence of placental lakes is associated with a 72% positive predictive value for placenta accreta.[102] Shih et al[101] recently reported the use of 3-dimensional (3D) power Doppler as a complementary technique for the antenatal diagnosis of placenta accreta, with the finding of hypervascularity or ''numerous coherent vessels'' having 97% sensitivity, 92% specificity, and 76% positive predictive value albeit in a small series. The 3D power Doppler pattern in placentas without accreta shows the cotyledonal and intervillous circulation in parallel to each other and perpendicular to the decidual plate, whereas in placenta accreta, these circulations cannot be discriminated because numerous dilated vessels fuse into a large vascular complex involving the placental base.[101]

Magnetic resonance imaging has been used to confirm the diagnosis of placenta accreta or better delineate the presence or extent of an accreta if ultrasound is inconclusive, and the Royal College of Obstetricians and Gynaecologists (RCOG) recommends its use to complement ultrasound in equivocal cases.[70,103] Magnetic resonance imaging is most useful for posterior placenta previa and in the assessment of deep myometrial, parametrial, and bladder involvement.[104] Overall, MRI has a sensitivity of 80% to 88% and specificity of 65% to 100% in diagnosing accreta.[105] However, the reported predictive accuracy of MRI or US may not be observed in settings where placenta accreta is infrequently encountered. The most commonly cited MRI criteria on T2-weighted images for the diagnosis of placenta accreta include dark intraplacental bands, heterogenous signal intensity in the placenta, focal areas of uterine bulging, and loss of interface with adjacent organs.[106] Although some authors believe that gadolinium-enhanced MRI improves the delineation between myometrium and placenta increasing specificity and no adverse fetal outcomes have been reported, intravenous administration of gadolinium during pregnancy is controversial as gadolinium crosses the placenta.[70,107] There is no evidence that MRI improves outcomes or pregnancy management.[89]

Elevated second-trimester maternal serum α-fetoprotein levels have been associated with placenta accreta. Zelop et al[108] noted a direct relationship between extent of placental invasion and the elevation of this analyte. Hung et al[109] observed that an MSAFP greater than 2.5 multiples of the median (MoM) and free β-hCG greater than 2.5 MoM were independently associated with placenta accreta. No serum markers have been evaluated prospectively to determine optimal screening or diagnostic thresholds. However, MSAFP testing among women with increased risk for placenta accreta may be appropriate even among patients who otherwise do not desire prenatal diagnosis or screening.

Zaitoun et al[28] and Simonazzi et al[110] suggest a role for measurement of cell-free placental mRNA in maternal plasma in increasing diagnostic accuracy in cases of placenta accreta as higher circulating levels of mRNA for *hPL*, *KiSS1*, *PLAC1*, and *VEGF* genes were associated with placenta accreta.

First-trimester diagnosis of placenta accreta is possible although these entities may have historically been categorized as cervical or cesarean scar ectopic pregnancies.[111] Massive hemorrhage after first-trimester suction curettage or a mass between the uterine wall and bladder with rising β-hCG after dilation and curettage may suggest a placenta accreta.[112,113]

Antepartum Management

Patients with placenta accreta should be scheduled for delivery in an institution with appropriate surgical facilities and a blood bank that can facilitate transfusion of large quantities of blood products. Maternal oral iron supplementation or intravenous iron therapy to maximize iron stores and oxygen-carrying capacity may be beneficial. Other than serial cervical lengths to assess risk of hemorrhage, antepartum surveillance is not necessary unless clinically indicated as placenta accreta itself is not associated with an increased risk of intrauterine growth restriction or fetal death.[114,115]

Delivery Considerations

Timing of delivery in cases of placenta accreta is controversial and depends on specific clinical circumstances and the extent of placental invasion.[89] A recent decision analytical model suggests that delivery at 34 weeks of gestation may be optimal and that amniocentesis for determination of FLM does not improve outcomes and is not recommended.[116] To reduce the likelihood of unscheduled emergent delivery at term, Pacheco and Gei[117] recommend delivery between 34 and 37 weeks without documentation of FLM by amniocentesis if no antepartum bleeding or other complication arises, and if there is debate on the timing of delivery at 34 weeks or later, these authors favor delivery to prevent emergent bleeding and emergent deliveries if the cervix is less than 30 mm and the gestational age greater than 34 weeks.

On the basis of the current literature, delivery in cases of placenta accreta uncomplicated by antepartum hemorrhage should be planned and occur by 37 weeks after administration of antenatal corticosteroids without confirmation of lung maturity. Patients

with placenta accreta and a history of antepartum bleeding and/or a cervix less than 30 mm should have planned delivery at 34 weeks after antenatal corticosteroid administration. These recommendations balance the risk of prematurity with the risk of emergent unplanned delivery for hemorrhage or labor.

A multidisciplinary team approach is best to reduce complications and minimize overall morbidity and mortality with preoperative consultations including anesthesiology, maternal-fetal medicine, gynecologic oncology, urology or urogynecology, general or vascular surgery, and interventional radiology.[107,118,119] Eller et al[120] demonstrated that maternal morbidity is reduced in women with suspected placenta accreta who deliver in a tertiary hospital with a multidisciplinary care team. Russo et al[121] also reported favorable maternal and fetal outcomes with a multidisciplinary team approach to management of placenta accreta.

Surgery for placenta accreta is typically prolonged with mean published operative times of 2 to 3 hours, and general anesthesia may be most appropriate in cases of anticipated severe hemorrhage, although the required amount of blood products is difficult to predict.[122] Average intraoperative blood loss is 2 to 5 L, although 10 L of blood loss has been reported.[114,122] O'Brien et al[6] found that 90% of patients with placenta percreta were transfused with 40% receiving 10 or more units of packed red blood cells (PRBCs), whereas Warshak et al[69] reported that 75% of placenta accreta cases required blood transfusions with a mean of 5.4 (2.1) units of PRBCs. A series of placenta accreta cases from New York–Presbyterian Columbia University Medical Center from 1994 to 2008 reported a 95% incidence of transfusion. with 39% requiring 10 or more units and 11% requiring 20 or more units.[123] Snegovskikh et al[124] recommend a massive transfusion protocol be implemented at any institution providing obstetrical services. Stotler et al[123] describe a multidisciplinary team approach for predelivery transfusion planning to ensure adequate resources are available to optimize maternal outcomes.

Immediate preoperative ultrasound mapping of placental location can assist in determining optimal approach as abdominal and uterine incisions can be planned to provide adequate visualization and avoid disturbing the placenta before delivery of fetus.[107] Perioperative ureteric stent placement can facilitate palpation of ureters intraoperatively, although ureteric trauma has not been significantly reduced with this approach in retrospective series.[125] However, Ng et al[118] reported a lower incidence of urologic complications after preoperative urologic assessment with placement of temporary ureteral catheters in a small series. Prophylactic antibiotics should be administered 1 hour before surgery and repeated if the surgery is prolonged or if heavy bleeding occurs.[126]

Endovascular Interventions

Preoperative pelvic artery occlusion has been recommended to reduce intraoperative blood loss with inflation of balloons after delivery of the infant, although it has not been confirmed to either improve outcomes or reduce blood loss.[125,127,128] However, Tan et al[129] and Carnevale et al[130] reported their experiences with prophylactic balloon occlusion of the internal iliac artery after fetal delivery and before performance of hysterectomy for placenta accreta and demonstrated a reduction in blood loss and transfusion requirements. Prophylactic pelvic artery catheterization and embolization can decrease perioperative blood loss and allow for uterine preservation, although some investigators similarly report no evidence that these techniques reduce the need for cesarean hysterectomy or the amount of operative blood loss.[127,131] Catheter placement can result in insertion site hematoma, abscess, tissue infarction, and necrosis.[132] Bishop et al[133] reported multiple complications after using prophylactic internal iliac artery balloon catheterization in a patient with placenta percreta including bilateral pseudoaneurysms, unilateral arterial rupture, and vascular compromise secondary to thrombus formation. Further research is required to determine the optimal intraoperative approach, and in the absence of data from large randomized controlled trials, controversy still exists about the safety and efficacy of endovascular interventions.[134] Although O'Rourke et al[135] describe cesarean delivery in an interventional radiology suite, the IR suites at most institutions may not be suitable for dealing with major obstetric hemorrhage and Kodali[136] proposed criteria for the optimal IR suite for complicated cesarean deliveries.

Anesthesia Management

Although regional anesthesia for cesarean delivery is associated with significantly fewer complications, general anesthesia is preferred in most accreta cases[137–139] owing to the significant risk of massive hemorrhage with profound hypotension and coagulopathy and the need for hysterectomy after cesarean delivery.[124] Recently, some authors have advocated a combination of regional and general anesthesia with cesarean delivery performed under regional anesthesia allowing the mother to be awake during delivery of the baby followed by conversion to general anesthesia

for performance of the hysterectomy.[140,141] Parva et al[138] reported a multidisciplinary approach to placenta percreta that incorporated regional anesthesia for preoperative placement of bilateral iliac artery balloons and delivery of the infant followed by general anesthesia for the subsequent supracervical hysterectomy.

Operative Considerations

Dorsal lithotomy positioning allows direct evaluation of vaginal bleeding and placement of ureteral stents as well as allowing space for an additional assistant. Pfannenstiel incision is reasonable, although an infraumbilical median or paramedian vertical skin incision may offer improved visualization and access for fundal or posterior hysterotomy and for hysterectomy.[107,142] Intraoperative ultrasound with the ultrasound probe covered by a sterile sleeve can guide the location of the uterine incision to avoid placental disruption. A posterior uterine wall incision after exteriorization of the uterus may also be helpful.

Hysterectomy should follow delivery of the infant without any attempt to remove the placenta before the hysterectomy is undertaken. In rare cases in which removal of the uterus is not possible or too dangerous because of extensive invasion into surrounding pelvic tissues, conservative therapy with the uterus and placenta left in situ has been reported.[107,143] Postoperative methotrexate or selective arterial embolization has also been reported although serious complications including severe hemorrhage with the need for delayed hysterectomy and septic shock have been reported with conservative management.[144] Delayed hysterectomy may be a valid consideration because decreased vascularity may make surgery technically easier, although the optimal timing for delayed hysterectomy is unknown because of the sometimes abrupt onset of hemorrhage.[145]

After delivery of the infant, the placenta should be left in situ after the umbilical cord is ligated and cut and the uterus should be closed rapidly to limit incisional edge bleeding. In unanticipated cases with a focal area of partial accreta identified on removal of the placenta, placement of deep myometrial sutures in multiple 3-cm squares in the area of placental invasion may achieve hemostasis.[146] The use of an intrauterine tamponade balloon like the Bakri balloon has also been reported for persistent bleeding from a localized accreta.[147]

Careful dissection of the retroperitoneal space and judicious devascularization away from the uterine wall is very important when performing a cesarean hysterectomy for placenta accreta. Special attention should be paid to reduce tearing through friable, vascular tissue near the uterine corpus and invading placenta and avoid puncturing the serosa overlying the placenta as heavy bleeding is possible. Cesarean hysterectomy with placenta in situ compared with other cesarean hysterectomies involves a greater need to protect the ureters while keeping a margin from the cervical placental mass and is akin to a modified radical hysterectomy requiring an experienced pelvic surgeon.[119,148] Plauché et al[149] reported a technique for rapid control of the uterine blood supply to stop vaginal bleeding at the time of cesarean hysterectomy where the uterine vascular pedicles are clamped but not ligated until after the entire uterine blood supply has been interrupted. Although this technique may be useful in certain circumstances, it has not been proven superior to the traditional technique of sequential clamping, cutting, and ligation of vascular pedicles in reducing blood loss or improving postoperative outcomes. Hoffman et al[119] describe their surgical approach to cesarean hysterectomy with ureteral stents and the use of an ENDO-GIA automatic stapling/cutting device for transection of vascular pedicles, vaginal fornix, and uterosacral ligaments with outcomes similar to more traditional techniques.

Preoperative cystoscopy may be useful, but intraoperative cystotomy may be needed to clarify the extent of placental invasion into the bladder after devascularization of uterus.[150,151] The invaded portion of the bladder can be excised or left attached to the uterus if the bladder trigone is not involved. Attempts to dissect the adherent bladder wall from the uterus should be avoided because of the risk of significant bleeding because much of the placental blood supply in cases of percreta is derived from collateral bladder vessels, and despite ligation of the uterine arteries, massive hemorrhage can occur from placenta/bladder interface.[119] Matsubara[152] reported a ''bladder-opening'' technique for cesarean hysterectomy in cases of placenta percreta with bladder invasion where the lateral wall of the bladder is cut with an ENDO-GIA automatic stapling/cutting device to allow resection of the cranial, invaded portion of the posterior bladder wall with the uterus and thus reduce hemorrhage and accidental bladder injury. The Pelosi technique for cesarean hysterectomy via ''retrovesical LUS bypass'' in cases of placenta percreta with bladder invasion may also reduce hemorrhage and bladder injury but is technically more difficult.[148]

Hematological Considerations

Blood product replacement strategies have seen remarkable refinement and improvement with recent

insights into early coagulopathy and from military experience in Afghanistan and Iraq with the administration of fresh-frozen plasma (FFP) and platelets in 1:1:1 ratio with PRBCs and limited early aggressive use of crystalloids and colloids resulting in a more rapid correction of coagulopathy, decreased need for PRBC transfusion postoperatively, and reduced mortality.[153–157] Although this new strategy from the US Army's Institute of Surgical Research known as Damage Control Resuscitation has shown promising results in civilian trauma patients, there are no comparable data on its risks and benefits in pregnancy, and extrapolation of data from nonpregnant patients in military and civilian trauma centers to massively bleeding parturients should be done with caution.[124,158] Real-time noninvasive monitoring of hemoglobin for pregnant patients during cesarean hysterectomy via multiwavelength pulse co-oximetry may play a role in guiding transfusion therapy and reducing inappropriate transfusions and complications after massive transfusions.[159] Preoperative autologous blood donation is not cost-effective and is recommended only for patients with rare blood types or alloimmunization to rare antibodies for whom immediate availability of blood products may be difficult.[160]

Investigators also recommend early administration of cryoprecipitate to parturients because higher-than-previously recommended levels of fibrinogen are necessary for adequate hemostasis.[161] Factor VIIa may be beneficial in treatment of uncontrollable obstetric hemorrhage, although it is more effective in the presence of fibrinogen levels greater than 100 mg/dL.[162] Caution is advised because of the potential for vascular thrombosis and thromboembolic events after its use, although a dose of 81.5 to 92 μg/kg significantly reduced hemorrhage in 76% to 85% of women without an increased incidence of thromboembolic events.[163–165]

Intraoperative cell saver technology may be appropriate for emergent obstetric use, but prospective studies are needed.[166] Current filtering technology eliminates the theoretical concern for amniotic fluid embolism from fetal cellular debris and amniotic fluid, although the risk of alloimmunization from fetal red blood cells remains.[160,167] However, investigators have reported episodes of severe hypotension related to use of cell saver during cesarean delivery.[168]

Options for persistent hemorrhage with placenta accreta include internal iliac artery ligation, pelvic artery embolization, placement of pelvic pressure packing, and infrarenal aortic compression or clamping.[107] Once major bleeding has been controlled, topical agents such as Gelfoam, Surgicel, Avitene, FloSeal, or fibrin glue may be used to help manage oozing. However, when all else fails, compressing the bleeding site with a pelvic pressure pack whose tail exits the vagina or the anterior abdominal wall may be a useful technique for posthysterectomy bleeding, leaving the pack in situ for 24 to 48 hours and initiating broad-spectrum antibiotics.[107,169] Dildy et al[169] reported that the pelvic pressure pack successfully controlled bleeding in 82% of cases. Such a technique has been reported as treatment for ruptured abdominal aortic aneurysm repair.[170]

Conservative Management

Conservative management of placenta accreta has been proposed to reduce morbidity and mortality as well as preserve the uterus for future reproduction and may be appropriate in women who desire more children or in cases of placenta percreta invading adjacent organs.[107,171] Conservative management involves a fundal or posterior uterine incision that avoids the placenta to facilitate delivery of the infant followed by closure of the uterine incision with the placenta left in situ.[172] Twenty percent of conservatively managed cases may undergo unplanned hysterectomy and 14% to 36% are associated with postoperative infections.[107,173] In a recent series of 167 patients with placenta accreta, conservative management was successful in 78.4% of cases with severe maternal morbidity in 6% of cases and spontaneous placental resorption in 75% of cases, with a median time from delivery of 13.5 weeks.[171]

There are significant risks of late hemorrhage, infection, coagulopathy, and recurrence of placenta accreta among those patients who have had conservative management that should be discussed at the time of informed consent.[173,174] There is currently insufficient evidence to support the use of uterine artery embolization, adjuvant methotrexate, or prophylactic antibiotics with conservative management.[107,117] Although useful in the treatment of gestational trophoblastic disease, use of methotrexate may be potentially dangerous in a mature placenta with very few rapidly dividing cells and methotrexate's association with bone marrow suppression is undesirable in patients with a significant risk of infection.[107] Bretelle et al[175] reported puerperal fever occurring in approximately 14% and endometritis in 10% of conservatively managed patients with placenta accreta. Chiang et al[176] reported a case of septic shock as a complication of conservative management of placenta accreta despite prophylactic antibiotics. Morgan and Atalla[177] recently reported 2 cases in which mifepristone and misoprostol were successfully used in the management of placenta accreta after vaginal delivery with retained placenta.

Lee et al[178] reported 2 cases of conservative management of placenta percreta with no significant hemorrhagic or infectious complications or the need for extensive bladder reconstruction by using internal iliac balloon occlusion, leaving the placenta in situ, intraoperative and postoperative methotrexate administration, and delayed hysterectomy performed when the quantitative β-hCG approached zero. Dueñas-Garcia et al[179] reported use of the uterine artery pulsatility index (PI) in a series of cases of conservative management of placenta accreta demonstrating better correlation of the uterine artery PI with persistence of the uteroplacental circulation than the quantitative serum β-hCG levels. These investigators also noted that placental degeneration with conservative management is not accelerated by the use of methotrexate. There are no guidelines regarding optimal postdelivery follow-up of conservatively managed patients with placenta accreta, although postpartum hemorrhage may occur up to 105 days after delivery.[171] Pacheco and Gei[117] recommend serial ultrasounds to assess placental involution and frequent visits to detect early signs of sepsis and delayed hemorrhage. Conservative management of placenta accreta has also been reported in a Jehovah's Witness.[180] Approximately 32% of physicians in a recent cross-sectional survey of maternal-fetal medicine providers in the United States registered with the Society for Maternal-Fetal Medicine had attempted conservative management, although most believes that hysterectomy is the only management option for placenta accreta.[181]

VASA PREVIA

Vasa previa is a rare but potentially catastrophic complication of pregnancy in which fetal vessels run through the fetal membranes and are at risk for rupture with subsequent fetal exsanguination. Vasa previa is rare and estimated to affect between 1 in 2500 and 1 in 5000 deliveries.[182,183] It is associated with 60% fetal mortality rate if unrecognized.[2] When diagnosed prenatally by ultrasound, the infant survival rate is 97%, whereas a 44% survival rate is found in cases not diagnosed prenatally.[182] Risk factors for vasa previa include low-lying placenta in the second trimester, multiple gestations, succenturiate or bilobed placenta, and IVF.[184–186] The first report of ultrasonographic diagnosis of vasa previa in the literature appeared in 1987.[187] Ultrasonographic findings of velamentous cord insertion and the suspicion of abnormal vessels in the region of the cervix are considered warning signs of vasa previa.[186]

Vasa previa may occur as a result of velamentous umbilical cord insertion into the placenta (type I) where the umbilical vessels course through the fetal membranes before inserting into the placental disk with the unsupported vessels overlying the cervix or it may also result from a bilobed or succenturiate placenta (type II) where the vessels connecting the placental lobes are overlying the cervix.[183]

Prenatal Diagnosis

The only significant predictors of neonatal survival are prenatal diagnosis and gestational age at delivery, and prenatal diagnosis is the most important factor in reducing fetal loss due to vasa previa.[2,8] Vasa previa may be diagnosed prenatally using ultrasound. Routine obstetric ultrasound should include assessment of placental site, number of placental lobes, and evaluation of placental cord insertion site. When multilobed or succenturiate placental lobes, low-lying placenta, or velamentous cord insertion are identified on transabdominal ultrasound, a detailed examination of LUS and cervix should be performed via TVUS. Grayscale ultrasound can identify the placental cord insertion in most cases, but power or color Doppler should be used to facilitate diagnosis.[188] There is a high specificity and sensitivity for vasa previa with Doppler ultrasound. Hasegawa et al[30] demonstrated that the most significant ultrasound findings associated with vasa previa may be an umbilical cord insertion site located on the LUS and a velamentous cord insertion. Vasa previa has been diagnosed prenatally using 3D ultrasonography.[186,189] Transvaginal 3D power Doppler provides an excellent means of visualizing the entire LUS but similar information can be obtained via 2D TVUS probe. Patients with risk factors for vasa previa including those with bilobed, succenturiate and low-lying placentas and those pregnancies with multiple gestations or resulting from IVF should have routine color Doppler sonography of the LUS near the cervical os to identify the placental cord insertion and to assess for the presence of vasa previa.

Maternal positional changes, Trendelenburg position, and gentle manual elevation of fetal presenting part aid in visualizing the fetal vessels when compressed by the fetal presenting part. Kuwata et al[190] reported that fetal head engagement can prevent correct diagnosis in a case where vasa previa mimicked an echolucent forebag-like structure on ultrasound without color Doppler flow. Hasegawa et al[191] reported evaluation of the umbilical cord insertion site in the late first or early second trimester with follow-up in cases of low cord insertion during the

late second or early third trimester as a useful means of detecting vasa previa. Kikuchi et al[192] reported that MRI may aid in the assessment of number and location of placental lobes when ultrasound diagnosis of vasa previa is difficult.

Unfortunately, many cases of vasa previa have been identified only at the time of vessel rupture in labor. Vaginal bleeding is followed by fetal distress and death if emergent delivery is not expedited because total fetal exsanguination can occur in 10 minutes. Theoretically, the Apt and Kleihauer-Betke tests can confirm fetal origin of blood in the vagina. However, in actual practice, both tests cannot be done quickly enough to be of any value. Electronic fetal monitoring may show an initial tachycardia rapidly followed by variable decelerations, bradycardia, and a preterminal sinusoidal pattern.[193] If cesarean delivery can be accomplished immediately, a good newborn outcome can be obtained with aggressive postnatal transfusion therapy.[194]

Antepartum Management and Delivery

There is no consensus on the optimal management strategy for vasa previa particularly about timing of elective delivery. On the basis of the 10% risk for rupture of membrane before labor and high associated fetal mortality rate with vasa previa, some authors suggest hospitalization at 30 to 32 weeks of gestation, administration of corticosteroids for acceleration of FLM, and delivery at 35 to 36 weeks without confirmation of FLM by amniocentesis.[8] Another approach that has been recommended includes weekly cervical length assessment after 30 weeks' gestation by TVUS, inpatient management if the cervix measures less than 2.5 cm, administration of betamethasone at 34 weeks' gestation for all patients, and delivery at 35 weeks without FLM testing.[25] A recent decision tree analysis also suggests that the optimal timing for delivery with vasa previa is 34-35 weeks after steroid administration without confirmation of FLM as amniocentesis for verification of FLM did not improve outcomes at any gestational age.[195]

Although there are limited data and experience, type II vasa previa is amenable to experimental in utero therapy. Chmait et al[196] successfully demonstrated third-trimester fetoscopic laser ablation of type II vasa previa as a prophylactic or therapeutic measure to delay delivery if symptomatic preterm labor and/or cervical shortening developed. Theoretically, as the size of the placental lobe to be lost increases after laser ablation, the risk of placental insufficiency may have short-term or long-term consequences for fetal well-being. Quintero et al[197] previously demonstrated the first successful in utero laser ablation of type II vasa previa at 22 weeks' gestation and subsequent spontaneous rupture of membranes at 27 weeks' gestation without fetal exsanguination.

A high index of suspicion and a meticulous approach to diagnosis provide the best opportunity for a favorable outcome. As with placenta accreta, intraoperative ultrasonography is useful to map the fetal vessels and make the optimal uterine incision.[198] Although difficult, it may be desirable to deliver the fetus en caul, with intact membranes, by avoiding incising the amniotic membranes.

CONCLUSIONS

This review was intended to provide an evidence-based approach to the diagnosis and management of 3 major causes of second- and third-trimester bleeding: placenta previa, placenta accreta, and vasa previa. It should aid obstetricians in the assessment of risk factors associated with abnormal placentation and in the sonographic evaluation of placenta previa, placenta accreta, and vasa previa. It should also facilitate the formulation of antepartum management and delivery plans for these patients and familiarize obstetricians with the surgical and medical options available in the management of abnormal placentation. Optimal maternal and fetal outcomes for these high-risk pregnancies result from accurate prenatal diagnosis and comprehensive multidisciplinary preparation.

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