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FIGO consensus guidelines on placenta accreta spectrum disorders: Prenatal diagnosis and screening★,§

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1. Introduction

Recent population studies have shown that placenta accreta spectrum (PAS) disorders remain undiagnosed before delivery in half [1,2] to two-thirds of cases [3]. In a series from specialist diagnostic units in the USA, around one-third of cases of PAS disorders were not diagnosed during pregnancy [4]. Maternal mortality and morbidity are reduced when women with PAS disorders, particularly the invasive forms—placenta increta or percreta—deliver in a center of excellence by a multidisciplinary care team with experience in managing the surgical risks and perioperative challenges presented by these disorders [5–8]. Transfer to a center of excellence, however, relies on both recognition of the women at risk of PAS disorders and on accurate prenatal diagnosis.

Current prenatal diagnosis rests on subjective interpretation of “typical” sonographic findings or signs with two-dimensional (2D) grey-scale and color Doppler imaging. Many signs have been reported in the literature with varying descriptions as to their sensitivity and specificity [9]. The published literature is difficult to interpret because of several problems in the definition, terminology, and diagnosis of this disorder [10]. To improve consistency and allow appropriate comparison of different imaging markers, panels of experts have published consensus statements that aim to standardize the descriptions and minimum requirements for an ultrasound scan to diagnose PAS disorders [11,12].

Magnetic resonance imaging (MRI), although widely employed, has yet to

clearly demonstrate a significant improvement in management or pregnancy outcomes [13]. MRI is expensive and requires expertise that is rarely available in most low-income countries and many medium-income countries. MRI is currently only recommended as an adjunct to ultrasound imaging by many professional bodies throughout the world including the Royal College of Obstetricians and Gynaecologists (RCOG) in the UK [14]. Irrespective of the imaging modality used, prenatal diagnosis of PAS disorders remains subjective, with accuracy depending on the experience of the operator, which has so far been limited by the rarity of the condition and the lack of training programs similar to those existing for the screening of fetal aneuploidies and fetal anatomical defects, such as congenital heart defects.

PAS disorders are a growing obstetric issue and with the continuous increase in cesarean deliveries more studies are being published yearly. The definitive diagnosis, however, can only be made clinically at delivery and should be confirmed by histopathology wherever possible. This chapter reviews the various prenatal diagnostic techniques described in the international literature for the diagnosis of PAS disorders. As abnormal placentation is a spectrum disorder including both abnormal adherence (placenta creta) and abnormal invasion (placenta increta and placenta percreta), the term PAS disorders is used here as the overarching descriptor of the whole condition.

2. Ultrasound imaging

Different ultrasound imaging techniques have been used over the last 30 years to diagnosis PAS disorders in the second and third trimesters of

pregnancy, including grey-scale and color Doppler imaging and/or three-dimensional (3D) power Doppler sonography. A recent systematic review showed that since the first ultrasound descriptions of cases of PAS disorders in the early 1980s, 1078 cases including 38 case reports and 53 series have been reported in the international literature [15].

2.1. Ultrasound for the diagnosis of PAS disorders

A systematic review and meta-analysis [9] of ultrasound studies involving 3707 pregnancies at risk of PAS disorders found that the overall performance of ultrasound is excellent, with a sensitivity of 90.72% (95% CI; 87.2–93.6), specificity of 96.94% (95% CI, 96.3–97.5), and diagnostic odds ratio (DOR) of 98.59 (95% CI, 48.8–199.0). A more recent systematic review and meta-analysis of 14 cohort studies that included 3907 pregnancies presenting with placenta previa or low-lying placenta and one or more prior cesarean deliveries identified 328 (8.4%) cases of placenta previa accreta out of which 298 (90.9%) were diagnosed prenatally by ultrasound [16]. The pooled performance of ultrasound for the prenatal detection of placenta previa accreta was higher in prospective than retrospective studies with DORs of 228.5 (95% CI, 67.2–776.9) and 80.8 (95% CI, 13.0–501.4), respectively.

2.2. The ultrasound signs

The first ultrasound sign suggesting PAS disorders described by grey-scale ultrasound imaging was the “loss of the hypoechoic retroplacental (clear) zone,” which is thought to represent an abnormal extension of the placental villi through the decidua basalis into the myometrium [17]. The presence of

numerous large or irregular lacunae directly connected to a feeding vessel has also been repeatedly reported as a reliable grey-scale ultrasound sign [17,18]. However, throughout the literature the reported sensitivity of grey-scale imaging ranges widely between 50% and 87% [9,16–19]. The incorporation of CDI has enabled better visualization of the uteroplacental circulation [9,16,17,20,21] and indicated that most cases of PAS disorders are associated with hypervascularization patterns (tornado vessels), within the placenta and between the placental basal plate or subplacental zone and underlying tissues (myometrium, bladder wall). The combination of grey-scale and color Doppler imaging ultrasound markers is reported to have increased the sensitivity of ultrasound imaging to around 90% with negative predictive values ranging between 95% and 98% [9].

There is wide variation in prenatal detection rates depending on the ultrasound signs used (Table 1), operator's experience, scanning conditions, equipment used, and gestational age. In particular, color Doppler imaging is more susceptible to operator error than grey-scale imaging. Differences in detection rates between studies can also be attributed to a combination of limited sample size, retrospective design, and variability of study inclusion criteria, and confirmation of diagnosis of PAS disorders at delivery and/or by histopathology [9,15,16]. In particular, as with all diagnostic techniques reliant on subjective opinion, the recorded presence or absence of each sign will be influenced by the operator's interpretation of what constitutes that marker. This is particularly important for clinicians who may not have had much experience with ultrasonography of the placenta. Interestingly, the results of

well-conducted prospective cohort studies by Finberg and Williams [18] and Comstock et al. [21] indicate that the sensitivity and specificity of grey-scale imaging alone in screening for placenta previa accreta are high when performed by expert operators.

In an attempt to reduce errors due to the subjectivity involved in making this diagnosis and ensure that all operators are using the same description for the same sign, the European Working Group on Abnormally Invasive Placenta (EW-AIP) recently proposed a standardized description and name for all the ultrasound signs used for the prenatal diagnosis of placenta accreta [12]. These are shown in Table 2. As the performance of each of the signs remains unclear from the published literature, an international expert group used the EW-AIP descriptors and a Delphi technique to generate a standardized pro forma for the minimum reporting requirements when performing an ultrasound assessment to diagnose PAS disorders [11]. A systematic review using this new standardized description for ultrasound examination of PAS disorders found that the loss of the clear zone (62.1%) and the presence of bridging vessels (71.4%) were the most common ultrasound signs found in cases of placenta creta. For placenta increta, a loss of the clear zone (84.6%) and subplacental hypervascularity (60%) were the most common ultrasound signs, whereas placental lacunae (82.4%) and subplacental hypervascularity (54.5%) were the most common ultrasound signs in placenta percreta [15].

Due to wide heterogeneity in terminology used to describe the grades of PAS disorders and differences in study design, no ultrasound sign or combination

of ultrasound signs is specific for the depth of accreta placentation [15-17]. In addition, accreta implantation is not homogeneous combining adherent and invasive villous tissue. Within this context, it would be pivotal that authors of prenatal diagnosis series should provide detailed data on the degree of depth villous invasion for each cases included in their study. It is also essential that future studies use standardized criteria for ultrasound imaging, clinical diagnosis and pathological examination to ensure good audit of clinical practice, research, improved teaching, and most importantly, better patient outcome.

2.3. Models for improving ultrasound prediction

A single-center retrospective cohort of 184 women with one or more prior cesarean deliveries and an ultrasound diagnosis of placenta previa or low-lying placenta used linear logistic regression and multiparametric analyses to generate a predictive equation. The analysis was performed using a receiver operating characteristic (ROC) curve, which indicated that the combination of the smallest sagittal myometrial thickness, intraplacental lacunae, and bridging vessels, in addition to the number of previous cesarean deliveries and placental location, generates an area under the curve of 0.87 (95% CI, 0.80–0.95) [22]. Each parameter was weighted to create a nine-point scale in which a score of 0–9 (placenta accreta index) provided a probability of invasion that ranged from 2%–96%, respectively. A similarly designed study of 92 cases of suspected accreta found that the area under the ROC curve was 0.85, with contribution from three variables: placenta previa, number of previous cesarean deliveries, and ultrasound suspicion [23]. These studies

indicate that combining diagnostic features associated with PAS disorders through mathematical modeling may improve accuracy of prenatal diagnosis compared with ultrasound alone. However, like most single center studies, these may have overestimated accuracy because they are conducted in centers specialized in prenatal diagnostics, and the overall number of cases of PAS disorders included in these series is small. The authors of both studies have also not differentiated between adherent and invasive cases in their series limiting the use of their data in clinical practice. In addition, the use of "morbidity adherent" to describe cases that are obviously invasive [22] is confusing and can lead to mis-interpretation of the data.

2.4. Technical issues in the diagnosis of PAS disorders

2.4.1. Transducer selection and approach

The ultrasound signs of abnormal placental invasion are most often described in the literature using transabdominal scanning and only 6 out of 14 cohort studies of placenta previa accreta reported on the use of transvaginal scanning (TVS) [16]. TVS is often recommended to identify the cervical canal, internal os, and the relationship between the leading placental edge and the internal os; it can also be used for a focused evaluation of the lower uterine wall and the bladder interface. Transabdominal scans can be improved by selecting a higher frequency (5–9 MHz) transducer (linear if possible), and carefully "walking" the scar from one end to the other, keeping the transducer perpendicular to the uterine wall.

2.4.2. Bladder filling

Ultrasound examination must be carried out with a full bladder (approximately 200–300 mL). The bladder outline is vital to identify the lower uterine segment, which is the presumed location of the previous cesarean delivery scar, thereby making the assessment of the placental position in relation to the presumed site of the scar possible. Without a full bladder, such signs as bladder wall interruption, placental bulge, and uterovesical hypervascularity cannot be appropriately assessed [17].

2.4.3. Probe pressure

Excessive probe pressure during transabdominal scanning can lead to the apparent loss of the retroplacental clear zone—one of the signs of invasive placentation. Therefore, this should be avoided. The loss of the retroplacental clear zone should be assessed with light probe pressure [17]. This pitfall is also much less likely to occur with TVS.

2.4.4. Use of color flow mapping and power Doppler

Excessive vascularity of the lower uterine segment is associated with abnormal invasion but is an inherently subjective sign. The normal uteroplacental interface is quite vascular but color Doppler imaging evaluation of this area is not part of a routine examination. Even experienced operators often do not have a baseline understanding of normal flow; it is, therefore, difficult to assess increased flow.

Appropriate machine settings are essential [24]. This includes the correct gain setting for the individual woman, often referred to as the subnoise gain. This is

the gain value where any artifact just disappears on reducing the level. This individual setting allows for optimal visualization of the flow despite differences in tissue attenuation (e.g. between different amounts of abdominal adipose tissue). Likewise, the correct velocity scale is crucial to appropriate visualization of the vasculature: if too high, low flow will not be seen; if too low, an “aliasing” artifact will appear. Appropriate machine settings and a full awareness of how changes to these settings will affect the appearance of the vascularity are pivotal to avoid these pitfalls.

3. The role of MRI in the diagnosis of PAS disorders

MRI has been used increasingly for the prenatal diagnosis of PAS disorders [25–29]. The main MRI features of placenta accreta include abnormal uterine bulging, dark intraplacental bands on T2-weighted imaging, heterogeneous signal intensity within the placenta, disorganized placental vasculature, and disruption of the uteroplacental zone (Table 1). A recent systematic review found that most studies are of small sample size, and thus sensitivity and specificity of MRI in diagnosing accreta placentation varies widely between 75% and 100% and 65% and 100%, respectively [28].

Two systematic reviews and meta-analyses have found that the diagnostic value of ultrasound imaging and MRI in detecting placenta accreta is comparable. The first one published in 2013 [29] including 13 studies reported a sensitivity of 83% (95% CI, 77–88), specificity of 95% (95% CI, 93–96), and DOR of 63.41 (95% CI, 29.04–138.48) for ultrasound imaging compared with a sensitivity of 82% (95% CI, 72–90), specificity of 88% (95% CI, 81–94) and

DOR of 22.95 (95% CI, 3.19–165.11) for MRI. The second study [28] including 18 studies found that the overall diagnostic accuracy of MRI was a sensitivity of 94.4% (95% CI, 86.0–97.9), specificity of 84.0% (95% CI, 76.0–89.8%), and DOR of 89.0 (95% CI, 22.8–348.1). The latter review also found that MRI has a high predictive accuracy in assessing both the depth and topography of placental invasion. It must be remembered that the MRI literature for prenatal detection of PAS disorders is biased because MRI is not a method used for screening. Only suspected cases are subjected to MRI examination.

It has been suggested that MRI is particularly valuable for detecting parametrial invasion by villous tissue [26]. However, parametrial invasion is not commonly reported by other authors. MRI may be considered in cases with a posterior placenta and suspicion of accreta, e.g. history of prior instrumentation. Increased depth and fetal parts may preclude a complete ultrasound evaluation of the uteroplacental interface of a posterior placenta. MRI is unaffected by these factors [27].

As the reported diagnostic performance of ultrasound imaging is so good in expert hands, it is debatable whether MRI can substantially add to the prenatal diagnosis of PAS disorders. Use of safe contrast agents may improve the diagnostic performance of MRI in the future.

4. Prenatal screening for PAS disorders

4.1. Clinical screening

Several risk factors for PAS disorders have been identified. These include advanced maternal age, multiparity, previous uterine surgery including curettage, assisted reproductive techniques, and previous cesarean delivery [19]. The most commonly described risk factor is the combination of previous cesarean delivery and placenta previa [30]. This combination also poses other problems, including increased risk of prenatal bleeding, access to the fetus for delivery, and the relatively poor contractility of the lower segment leading to greater postpartum blood loss.

The prevalence of PAS disorders in the general population of pregnant women is around 1.7 per 10 000 pregnancies [30,31]. However, the incidence of placenta previa accreta is 4.1% in women with one prior cesarean delivery and 13.3% in women with two or more previous cesareans [16], and continues to rise with the number of prior cesareans [30]. Thus, focusing the screening of PAS disorders on this group is more productive in terms of diagnostic yield. All women found to have an anterior low-lying (placental edge <2 cm from the internal cervical os after 16 weeks of gestation) or placenta previa should be asked if they have had a previous cesarean delivery during prenatal consultations and, if they do, they should be referred to a center with expertise in the prenatal diagnosis of PAS disorders.

4.2. Midpregnancy ultrasound screening

Ultrasound screening for PAS disorders is not routinely taught during ultrasound training courses. Introducing such a screening program has been discussed but never implemented. We are not aware of ultrasound courses

that train ultrasonographers who perform routine midtrimester ultrasound for detailed fetal anatomy examination in screening for PAS disorders. Identification of an anterior low-lying placenta or an anterior previa or a placenta previa covering the internal os in a woman with a history of previous cesarean delivery should prompt referral to the most experienced operator available (preferably with expertise in diagnosis of PAS disorders) for a more detailed scan to look for signs. All sonographers should be aware of the risk of PAS disorders, especially with an anterior low placenta or placenta previa, and should be aware of the referral pathway for further investigation if they have any concerns.

There are no prospective data on the ultrasound screening of PAS disorders at the routine midtrimester ultrasound examination by nonexpert operators [16]. Introducing such a screening program requires careful consideration, but is increasingly necessary owing to the constant rise in the number of cesarean deliveries.

4.3. First trimester screening for PAS disorders

Recently, it has been suggested that cesarean scar pregnancy represents a precursor of one of the different grades of PAS disorders [32–34].

Implantation of the gestational sac into a previous cesarean delivery scar is diagnosed using the following three criteria on TVS [35]:

(1) Gestational sac located anteriorly at the level of the internal os within a visible myometrial defect (thin or absent myometrium) at the site of the

previous lower segment cesarean delivery scar.

(2) Evidence of functional trophoblastic/placental circulation on color Doppler examination, characterized by high-velocity (peak velocity >20 cm/s) and low-impedance (pulsatility index <1) blood flow.

(3) To distinguish from a spontaneous abortion in progress look for a negative “sliding organs sign,” defined as the inability to displace the gestational sac from its position at the level of the internal os using gentle pressure applied by the transvaginal probe.

A recent systematic review and meta-analysis showed that cesarean scar pregnancy with positive embryonic/fetal heart activity managed expectantly is associated with a high burden of maternal morbidities including severe hemorrhage, early uterine rupture, hysterectomy, and severe PAS disorders [36]. However, this review included only 69 cases and thus there is still limited evidence on the natural history of cesarean scar pregnancy and in particular on the incidence of PAS disorders in women diagnosed with cesarean scar pregnancy in the first trimester of pregnancy.

Overall, a cesarean scar pregnancy, even if not accreta, is associated with a very high risk of obstetric complications due to the consequences of a major placenta previa i.e. massive obstetric hemorrhage. Thus, women diagnosed in the first trimester with a cesarean scar pregnancy should be counselled regarding the high risk of complications including hysterectomy. Because of the high risk in continuing the pregnancy, treatment in the first trimester should be considered [37]. The most experienced operator available should

follow up the patient, preferably one with expertise in the diagnosis of PAS disorders.

4.4. Biomarkers of PAS disorders

Several placental and fetal hormones routinely used in the screening of Down's syndrome have been found to have different concentrations in the serum of women with placenta previa accreta compared with those with a non-accreta previa [38–40]. At 11–12 weeks of pregnancy, human chorionic gonadotropin (hCG) and its free beta-subunit (β-hCG) are lower and pregnancy-associated plasma protein A (PAPP-A) is higher in the maternal serum of women with PAS disorders. By contrast, at 14–22 weeks, women presenting with a placenta previa are at higher risk of PAS disorders if serum β-hCG and alpha-fetoprotein (AFP) are above 2.5 multiples of the median (MoM) (OR 3.9; 95% CI, 1.5–9.9; and OR 8.3; 95% CI, 1.8–39.3, respectively) [41]. By contrast, no difference has been found in the amount of cell-free fetal DNA (cffDNA) in the maternal serum of women presenting with PAS disorders compared with normal controls [42]. Other biomarkers have been investigated retrospectively in the serum of women diagnosed with PAS disorders at delivery, but their lack of availability in hospital laboratories limits their use in clinical practice. Overall, biomarkers could be used with ultrasound imaging to screen for PAS disorders prenatally in a model similar to that used for aneuploidy screening; however, the benefit of this remains unknown until more prospective data are available.

5. Limitations of prenatal diagnosis

One should remember that prenatal diagnosis of PAS disorders is not a histopathological diagnosis. Small areas of abnormal invasion have been reported even in asymptomatic women, and are of little clinical significance [43]. Similarly a simply adherent placenta will not require major surgery and can often be managed conservatively. In such cases, lack of ultrasound signs despite histopathological evidence of abnormal invasion may be interpreted as “failure” of prenatal diagnosis by ultrasound. It can be argued that the purpose of prenatal diagnosis is to forewarn the obstetric team of the probability of significant maternal morbidity. Therefore, the aim of prenatal imaging should be to detect PAS disorders of clinical significance such as placenta increta and percreta [10–12,15–17]. It is therefore paradoxical and confusing that an increasing number of authors of prenatal diagnostic series include in their cohort both superficially adherent and invasive placenta under the morbidly adherent category. In addition, as many of these authors do not provide accurate clinical data on the differential diagnosis of the different categories of PAS disorders, it is difficult to separate retrospectively the noninvasive placenta accreta from the retained placenta. This has an impact on the epidemiology data and on determining the diagnostic accuracy of ultrasound and MRI.

A significant proportion of cases of placenta previa are associated with PAS disorders, particularly if the uterus is scarred and the placenta is anterior and/or covering the cervix. Even if no villous tissue is invading the uterine myometrium, access to the fetus is complicated by the position of the underlying placenta, the lower uterine segment adjacent to the placenta is

highly vascularized, and major hemorrhage can still occur. It would be incorrect to believe that major morbidity should be expected only if prenatal diagnosis of PAS disorders has been made.

It is also important to remember that although imaging is the best investigation modality available for prenatal identification of invasive placentation, the sensitivity and specificity are not 100%. In cases of false-negative prenatal diagnosis, the surgeon performing the cesarean delivery will use a low transverse uterine incision and this may lead to massive intraoperative hemorrhage, even before the fetus is delivered. By contrast, a false-positive diagnosis of PAS disorders will lead to an unnecessary midline vertical skin incision and a fundal uterine incision, thus increasing the risk of intraoperative and postoperative complications and the risk of PAS disorders and uterine rupture in subsequent pregnancies [16].

Conflicts of interest

The authors have no conflicts of interest to declare.

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Box 1. Recommendations for the evaluation of epidemiological data on placenta accreta spectrum (PAS) disorders.

Recommendations	Resource settings	Quality of evidence and strength of recommendation
Ultrasonography is a relatively inexpensive and widely available imaging modality and therefore should be the first line for the diagnosis of PAS disorders.	All	High and Strong
Women diagnosed with cesarean scar pregnancy in the first trimester should be counselled regarding the high risk of requiring a hysterectomy owing to PAS disorders. They should be followed up by the most experienced operator available, preferably one with expertise in diagnosis of PAS disorders.	All	High and Strong
At the mid-trimester examination for fetal anomaly, all women should be asked if they have had a previous cesarean delivery. If so, this should prompt careful assessment of the placental implantation site especially if it is anterior, low lying, or previa.	All	Medium and Strong
The ultrasound signs observed for the diagnosis of PAS disorders should be described using standardized protocols.	All	Medium and Strong
The recorded presence or absence of each ultrasound sign will be influenced by the operator's interpretation of what constitutes that marker.	All	High and Strong
MRI is not essential for making a prenatal diagnosis of suspected PAS disorders but may be useful in evaluating the pelvic extension of a placenta percreta or areas difficult to evaluate on ultrasound.	High-income	Medium and Weak

Table 1

Summary estimates of sensitivity and specificity of different ultrasound and MRI signs for the detection of PAS disorders[a]

Detection signs	Studies (n)	Patients (n)	% Sensitivity (95% CI)	% Specificity (95% CI)
Ultrasound signs				
Placental lacunae	13	2725	77.4 (70.1–83.1)	95.02 (94.1–95.8)
Loss of hypoechoic space	10	2633	66.2 (58.3–73.6)	95.8 (94.9-96.5)
Abnormalities of uterus–bladder interface	9	2579	49.7 (41.4–58.0)	99.8 (99.5–99.8)
Color Doppler abnormalities	12	714	90.8 (85.2–94.7)	87.7 (84.6–90.4)
MRI signs				
Uterine bulging	5	119	79.1 (60.3–90.4)	90.2 (76.2–96.4)
Heterogeneous signal intensity	6	143	78.6 (57.7–90.8)	87.7 (50.4–98.0)
Dark intraplacental bands on T2	6	146	87.9 (70.9–95.6)	71.9 (55.6–84.0)
Focal interruption of myometrium	4	119	92.0 (79.2–97.2)	75.6 (50.4–90.4)
Tenting of the bladder	2	74	80.0 (28.0–99.5)	98.6 (92.2–100)

[a] Adapted from D'Antonio et al. [9] and D'Antonio et al. [28].

Table 2

Unified descriptors (EW-AIP suggestions) for ultrasound findings in placenta accreta spectrum (PAS) disorders[a]

Descriptor	Finding
2D grey-scale	
Loss of the “clear zone”	Loss or irregularity of the hypoechoic plane in the myometrium underneath the placental bed (the “clear zone”)
Abnormal placental lacunae	Presence of numerous lacunae including some that are large and irregular (Finberg grade 3*)* often containing turbulent flow visible in grey-scale imaging
Bladder wall interruption	Loss or interruption of the bright bladder wall (the hyperechoic band or “line” between the uterine serosa and the bladder lumen)
Myometrial thinning	Thinning of the myometrium overlying the placenta to <1 mm or undetectable
Placental bulge	Deviation of the uterine serosa away from the expected plane, caused by an abnormal bulge of placental tissue into a neighboring organ, typically the bladder. The uterine serosa appears intact but the outline shape is distorted
Focal exophytic mass	Placental tissue seen breaking through the uterine serosa and extending beyond it. Most often seen inside a filled urinary bladder
Color Doppler imaging	
Uterovesical hypervascularity	Striking amount of color Doppler signal seen between the myometrium and the posterior wall of the bladder. This sign probably indicates numerous, closely packed, tortuous vessels in that region (demonstrating multi-directional flow and aliasing artifact).
Subplacental hypervascularity	Striking amount of color Doppler signal seen in the placental bed. This sign probably indicates numerous, closely packed, tortuous vessels in that region (demonstrating multidirectional flow and aliasing artifact)
Bridging vessels	Vessels appearing to extend from the placenta across the myometrium and beyond the serosa into the bladder or other organs. Often running perpendicular to the myometrium
Placental lacunae feeder vessels	Vessels with high velocity blood flow leading from the myometrium into the placental lacunae, causing turbulence upon entry

3D intraplacental hypervascularity	Complex, irregular arrangement of numerous placental vessels, exhibiting tortuous courses and varying calibers

[a] Modified from Collins et al. [12].