Special Report of the SMFM PAS US Marker Task Force: Placenta Accreta Spectrum: Consensus on Definition of Markers and Approach to the Ultrasound Examination in At-Risk Pregnancies.

The Society for Maternal Fetal Medicine (SMFM), American Institute of Ultrasound in Medicine (AIUM), American College of Radiologists (ACR), and Gottesfeld Hohler Memorial Society (GOHO) endorse this document. The American College of Obstetricians and Gynecologists (ACOG) and International Society of Ultrasound In Obstetrics and Gynecology (ISUOG) support this document. The Society of Radiologists in Ultrasound (SRU) approves this document.

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Abstract

Placenta Accreta Spectrum (PAS) includes the full range of abnormal placental attachment to the uterus or other structures, encompassing placenta accreta, increta, percreta, morbidly adherent placenta, and invasive placentation. The incidence of PAS has increased in recent years, largely driven by increasing rates of cesarean delivery. Prenatal detection of PAS is primarily made by ultrasound and is important to reduce maternal morbidity associated with the condition. Despite a large body of research on various PAS ultrasound markers and their screening performance, inconsistencies in the literature persist. In response to the need for standardizing the definitions of PAS markers and the approach to the ultrasound examination, the Society for Maternal-Fetal Medicine (SMFM) convened a task force with representatives from the American Institute of Ultrasound in Medicine (AIUM), the American College of Obstetricians and Gynecologists (ACOG), the American College of Radiology (ACR), the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG), the Society for Radiologists in Ultrasound (SRU), the American Registry for Diagnostic Medical Sonography (ARDMS) and the Gottesfeld-Hohler Memorial Ultrasound Foundation (GOHO). The goals of the task force were to assess PAS sonographic markers based on available data and expert consensus, provide a standardized approach to the prenatal ultrasound evaluation of the uterus and placenta in pregnancies at risk

for PAS, and identify research gaps in the field. This manuscript provides information on the PAS task force process and findings.

Key words: placenta accreta spectrum, accreta, increta, precreta, previa, maternal morbidity, maternal mortality, cesarean

Introduction

Placenta Accreta Spectrum (PAS), encompassing the terms placenta accreta, increta, percreta, morbidly adherent placenta, and invasive placentation, includes the full range of abnormal placental attachment to the uterus or other structures. There has been a dramatic rise in the incidence of PAS over recent years.[1] This rise is most notably driven by increasing rates of cesarean delivery. The risk is highest in the presence of placenta previa and prior cesarean(s).[1,2] PAS is associated with marked increase in maternal morbidity and mortality. The morbidity is primarily related to massive hemorrhage with associated organ damage, cesarean hysterectomy ,and need for critical care resources.[1,2] Prenatal detection of PAS allows for mobilization of multidisciplinary care teams and surgical planning, which reduces maternal morbidity.[3–8] Furthermore, the ability to correctly stratify the risk of PAS, including decreasing the risk with a “normal” ultrasound, reduces the possibility of iatrogenic complications associated with planned premature delivery, preoperative invasive procedures, and patient and provider anxiety.

The prenatal detection and risk stratification for PAS is primarily made by ultrasound. However, ultrasound is an operator dependent imaging modality with substantial variability in image quality among providers. Furthermore, placental location and challenging imaging conditions, including elevated BMI or posterior placentation, may impede the sonographic detection of PAS markers. There has been limited consensus on the optimal approach to the ultrasound evaluation of patients at risk for PAS, such as the appropriate timing of screening, need for transvaginal ultrasound imaging, use of color and pulsed Doppler, angle of placental insonation, and equipment settings.

Despite a large body of literature on various PAS ultrasound markers and their screening performance, important inconsistencies in results persist. This is primarily due to the retrospective design of most studies, lack of standardized definitions of PAS markers, lack of agreement on the optimal gestational age for assessment, and inconsistencies in the approach to the ultrasound evaluation of the placenta.[9] Furthermore, patients' *a priori* risks have significant influence on the positive predictive value of PAS markers, as recent data have shown that these markers are frequently present in low risk women.[10]

In response to the need for standardizing the definitions of PAS markers and the approach to the ultrasound examination, the Society for Maternal-Fetal Medicine (SMFM) convened a task force with the goals of assessing PAS sonographic markers based on available data and expert consensus, providing a standardized approach to the prenatal ultrasound evaluation of the uterus and placenta in pregnancies at risk for PAS, and identifying research gaps in the field. This manuscript provides information on the PAS task force process and outcomes.

Procedure

SMFM invited representatives from the American Institute of Ultrasound in Medicine (AIUM), the American College of Obstetricians and Gynecologists (ACOG), the American College of Radiology (ACR), the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG), the Society for Radiologists in Ultrasound (SRU), the American Registry for Diagnostic Medical Sonography (ARDMS) and the Gottesfeld-Hohler Memorial Ultrasound

Foundation (GOHO) to the PAS task force (Table 1). The PAS task force was organized into four subcommittees: first trimester markers, placental lacunae, utero-placental interface, and utero-vesical interface, which also included miscellaneous markers (cervical invasion, placental bulge, and exophytic mass). Each subcommittee was chaired by a PAS task force member and included at least two additional members. The authors SS and AA participated on all four subcommittees. Each subcommittee performed a detailed literature review of respective markers. This included the defintions of each marker, indication for the exam, reported diagnostic accuracy of each marker, gestational age at assessment, and optimal ultrasound approach for evaluation.[6,7,19–28,11,29–38,12,39–42,13–18] The task force held a face-to-face meeting in December 2018 in Boston, Massachusettes to review each subcommittee's findings and recommendations. Expert consensus opinion was obtained when available data could not provide clear definitions for each PAS marker and/or the optimal approach for screening. In addition, research gaps were noted.

Literature Review

As outlined in a recent Obstetrics Care Consensus, ultrasound is the primary screening modality for PAS.[7] Ultrasound markers of PAS can be seen early in the first trimester, although historically screening is predominantly performed in the second and third trimesters of pregnancy. The ultrasound marker with the strongest association with PAS is a persistent placenta previa at the time of delivery, in the setting of a prior cesarean delivery.[5,43] Other classic sonographic markers of PAS include the presence of placental lacunae (Figure 1), loss of the retroplacental hypoechoic zone (Figure 2), thinning of the retroplacental myometrium (Figure 3), hypervascularity of the utero-vesicle or retroplacental space (Figure 4), extension of placental tissue into the uterus/bladder, and placental bridging vessels (Figures 5 and 6).[11,39–41,44–46] The presence of excessive color Doppler flow in the retroplacental space, along with abnormal placental bridging vessels have also been associated with PAS (Figure 6).[6,7,46,47]

Task force members identified several significant limitations to the current literature on this subject. The majority of studies are retrospective in design, lack control "low-risk" comparison groups, and do not provide clear definitions of the PAS marker(s) being studied, which limits the ability to make comparisons between studies and combines many of the reported diagnostic performance statistics.[9] It is important to note that most studies were designed to highlight associations between ultrasound markers and PAS, thus results cannot be inferred to reflect on the diagnostic and predictive accuracy of these markers. Furthermore, the majority of the studies included cases with surgically or histologically confirmed placenta accreta, making it difficult to extrapolate information regarding the validity of PAS markers in the first-trimester ultrasound.

First Trimester

Several PAS ultrasound markers have been described in the first trimester. The prevalence and type of first trimester markers of PAS vary between the early first trimester (6-9 weeks of gestation) and the later first trimester (11-14 weeks of gestation).[11]

In a patient with a previous cesarean delivery, the implantation of a gestational sac in the lower uterine segment on ultrasound early in the first trimester is one of the most common first trimester marker for PAS. A cesarean scar pregnancy (CSP), defined as a gestational sac implanted in the lower uterine segment within or in close proximity to the cesarean scar, markedly increases the risk of PAS (Figure 7 and 8).[11,48,49] When a gestational sac is implanted within a cesarean scar 'niche', extrauterine extension of placental tissue and the need for hysterectomy is substantially increased.[50] Histopathologically, a CSP is not distinguishable from that of second trimester PAS, suggesting that they represent a continuum in the pathogenesis of the disease.[51] In one study of 68 patients with prenatally identified PAS confirmed at delivery and a technically adequate ultrasound examination between 6-9 weeks of gestation, all were noted to have a low implantation of the gestational sac.[11]

In the late first trimester, a low implantation of the gestational sac is identified in approximately 28% of patients with PAS (Figure 9A and 9B).[11] This is explained by the growth of the gestational sac towards the fundal portion of the endometrium as the pregnancy progresses. If the placenta is anterior and under the cesarean scar, it can remain anchored to the cesarean scar significantly raising the risk of PAS.

In a recent systematic review and meta-analysis evaluating the first trimester detection of PAS in high-risk women, a gestational sac implanted in close proximity to a uterine scar was identified in 82.4% (95% CI, 85.8-95.7%) of women with confirmed PAS.[52] However, the sensitivity of this finding in the same analysis was found to only be 44% (95% CI, 21.5-69.2%), highlighting the limitations of assessing risk in the first trimester. [52]

Other markers that have been traditionally described in the second and third trimester have also been identified in the late first trimester and are variably associated with PAS.[52] The definitions of the individual markers have been inconsistent but include the presence of placental lacunae, an abnormal bladder interface, uterovesicular hypervascularity and loss of the retroplacental clear zone. [11,16,28,53] This last marker is particularly helpful in determining the extent of PAS, carrying a sensitivity of 84.3% and diagnostic odds ratio (DOR) of 23.8 (95% CI: 10.6-57.2).[53] For cases that were ultimately determined to be placenta percreta at time of delivery, the sensitivity of this marker was 92.1% with a DOR of 20.4 (95% CI: 6.0-108.7).

Placental lacunae and posterior bladder wall interruption/abnormalities were also noted in the late first trimester in cases of percreta, each with sensitivities between 80-90%.[53] Anterior placentation at the first trimester sonographic evaluation is more common in women with PAS at delivery.[11,16,28] Similar to findings in the second and third trimester, the presence of multiple PAS markers in the first trimester increased the diagnostic accuracy.[52–54]

Second and Third Trimester

Placental Lacunae

The presence of placental lacunae have been commonly reported in association with PAS.[39,55,56] Often described as numerous, large, and irregular echolucencies within the parachyma of the placenta, placental lacunae should raise the concern for underyling PAS.[55,56] Prior studies in PAS differ substantially in the definition of lacunae with regards to the required size, number and presence of blood flow in lacunae. Lacunar blood flow has been described as low-velocity flow in some reports, while others report turbulent high-velocity flow.[9,26,34,57] Finberg and Williams, in their 1992 seminal work on ultrasound markers of PAS, proposed a placental lacunae vascular space grading system;,with grade 0 indicating no placental lacunae, grade 1+ including placentas with one to three small lacunae, grade 2+ containing four to six larger and irregular lacunae, and grade 3+ describing a placenta with many large and "bizzare" appearing lacunae thoughout (Figure 1). Grade 3+ should raise a high degree of concern for PAS.[55] Yang et al. investigated the association of lacunae with maternal complications in 51 pregnancies at risk for PAS, with a prior cesarean delivery and a persistent placenta previa.[38] The authors found that the need for cesarean hysterectomy and maternal complications positively correlated with the number of lacunae.[38] Furthermore, the absence of lacunae in pregnancies with placenta previa and prior cesarean delivery is a reassuring sign with negative predictive values ranging from 88-100% for PAS.[9,38,55]

Abnormal Utero-placental Interface

Abnormal utero-placental interface has been described as loss of the retroplacental hypoechoic zone, myometrial thinning and increased vascularity on color Doppler.[6,10,46] There is substantial variation in the definition and statistical performance of the loss of the retroplacental hypoechoic zone for predicting PAS.[9,13,39,46] The classic definition of myometrial thinning is a retroplacental myometrial thickness of less than 1 mm. However, only 50% of cohort studies of PAS provided a working definition of this marker.[46,47] In addition, myometrial thinning is often seen in advancing gestation and can be more pronouced in women with prior cesarean delivery.[58] This marker can be iatrogenically produced and/or exaggerated with undue transducer pressure, highlighting the need to minimize transducer pressure on the abdomen when examining the placenta.[41,46]

Utero-vesical interface

Utero-vesical interface markers include bridging vessels, increased vascularity between the uterus and bladder, and interruption of the bladder wall. Bridging vessels represent neovascularity atop the uterine sersosa and frequently within the utero-vesical interface, depending on placental position.[42,47,59] This color Doppler finding of neovascularity is found in the majority of cases of PAS and reflects the engorged myometrial vessels in the area of placentation. The hypervascular utero-vesicle interface also reflects dilation of the uteroplacental vasculature and the chaotic vascular growth and flow within this space.[46] Sensitivity and specificity of hypervascular utero-vesical interface is variably reported as ranging from 11-100% and 36-100%, respectively.[24,60–65] Bladder varicosities are often seen in the absence of PAS and in the setting of placenta previa.[42,59] In addition, hypervascularity of the lower uterine segment and/or cervix can be seen in placenta previa without PAS, highlighting the difficulty in assessing this marker. Interruption of the echogenic bladder wall, especially with placental tissue, is a clear marker of PAS as it represents extension of placental tissue beyond the uterus (Figure 6). Engorged vessels in the utero-vesical interface may result in ultrasound echo-drop out, thus mimicking placental extension into the the utero-placenta interface.[47]

Miscellaneous markers

There are numerous other miscellaneous markers for PAS that have been described. Of these, placental bulge, exophytic placental mass, and cervical vascular extension were reviewed by the committee. The placental bulge is described as a deviation of the uterine serosa, away from expected planes, changing the uterine contour (Figure 5 ,6 and 10).[13,23,47] In a small study comparing ultrasound and MRI features that may predict placental invasion, the placental bulge was found to have a specificity of 88%, highlighting this marker as a reassuring sign when absent.[23] An exophytic mass represents protrusion of placental tissue outside the uterus and when seen is diagnostic of placenta percreta. Similarly, the absence of this finding is reassuring, as it carries a 80-100% specificity, albeit with a maximal sensitivity of 42%.[23,34,61] In one systematic review of PAS, only cases of placenta increta and percreta had a placental bulge or an exophytic mass, highlighting their relative rarity in clinical practice.[46] Vascular cervical extension is defined by placental extension into the cervix involving at least the inner one third, best seen on transvaginal ultrasound. This marker performs poorly, however, as it was identified in greater than 50% of the time in a low risk cohort without PAS. [10]

Combined markers

When ultrasound markers are combined, their performance improves substantially, yielding sensitivity of 81.1% (95% CI, 69-94), specificity of 98.9% (95% CI, 98-100), positive predictive value of 90.9% (95%CI: 82-100), and a negative predictive value of 97.5 (95% CI: 96-99).[18] Thinning of the myometrium and loss of the retroplacental clear zone appear to have the highest interobserver agreements.[13] Most data regarding the predictability of PAS ultrasound markers have been derived in single centers with relatively high volume of PAS cases. The true sensitivity of these markers in the community setting remains unknown.

Existing Consensus Guidelines

The European Working Group on Abnormally Invasive Placenta (EW-AIP) and the International Federation of Gynecology and Obstetrics (FIGO) developed language outlining various PAS ultrasound markers and suggested standardized definitions for each.[40,41] The EW-AIP established a list of 11 PAS ultrasound markers (six in 2D greyscale, 4 in 2D color Doppler, and 1 in 3D power Doppler). This was derived from the analysis of 23 manuscripts reviewed by an expert panel. The panel placed importance on defining each PAS marker without ambiguity, but did not report on their predictive values.[41] The recent FIGO consensus guidelines for PAS prenatal screening and diagnosis listed the EW-AIP 11 markers along with their definitions, did not recommend using certain markers over others and acknowledged that none carry 100% sensitivity and specificity. The FIGO consensus guidelines also commented on the role of a cesarean scar pregnancy as the first trimester precursor to PAS.[40] In taking these published definitions into account, we reviewed the general utility of each ultrasound marker and utilized the FIGO/EW-AIP definitions when possible and appropriate. We also attempted to consolidate some ultrasound PAS markers to simplify language and streamline defintions.

Ultrasound Approach and Definitions of PAS Markers

General Considerations

We recommend starting the assessment with transabdominal imaging to obtain an overview of placental location and start to assess regions of concern. Transvaginal ultrasound is strongly recommended for the assessment of PAS. Transvaginal imaging optimizes resolution, and allows for detailed assessment of the lower uterine segment, posterior bladder wall and cervix. The bladder should be partially full. Color Doppler should be utilized to assess for vascularity and placental extension into the uterine wall and surrounding structions. The transducer should be adjusted to operate at the highest clinically appropriate frequency, realizing that there is a trade-off between resolution and beam penetration.[66] Ultrasound image magnification should be performed to enhance visualization of target regions. When assessing the retroplacental region, perpendicular orientation of the angle of insonation and applying minimal transducer pressure is recommended. Given the continuum of disease from cesarean scar pregnancy to PAS, screening for PAS should begin early in the first trimester and continue throughout the pregnancy until practioners have concluded whether there is sonograpahic concern for PAS.

First Trimester

In the first trimester, a detailed evaluation of the uterus is necessary to determine the location of the gestational sac or placenta (depending upon gestational age) in reference to the bladder, internal os and cesarean scar. When performing transvaginal ultrasound, the maternal bladder should be partially filled, enough to allow for a sonographic window, without over filling, which can result in distortion of the utero-vesical interface. The target area should be magnified to occupy at least one-half of the ultrasound image and focal zone(s) should be appropriately placed. After 10 weeks of gestation, color Doppler can be used to assess for the presence of hypervascularity and lacunae; when possible, color should be limited to the placental region, and not overlap the fetus. The definition of first trimester PAS markers and the proposed ultrasound approach is presented in tables 2 and 3, respectively.

Second and Third Trimesters

The antenatal diagnosis of PAS is most often made in the second and third trimester of pregnancy. Classic sonographic markers of PAS are typically decribed in women with anterior placenta previas and prior cesarean deliveries.[6,7]

Table 4 lists the proposed definitions of PAS ultrasound markers in the second and third trimesters of pregnancy. Other than placenta previa, placenta lacunae are frequently described as classic ultrasound markers of PAS. Lacunae can often be found in low risk non-PAS pregnancies, however, when present in women with risk factors, they carry the highest sensitivity of all 2D gray scale markers.[10,67] When lacunae are large, numerous, and with irregular borders, their association with PAS is increased.[55] Lacunae tend to congregate near the area of placental invasion; thus the presence of lacunae blood flow on gray scale and color Doppler is also associated with PAS.

Sonographic assessment of the utero-placental interface includes evaluation for loss of the retroplacental hypoechoic zone and thinning of the retroplacental myometrium.[6,9,13,39,46,47] The utero-placental interface is often inferior to the posterior bladder wall. Similar to other PAS markers in women with anterior placenta and prior cesarean delivery, the utero-placental interface is best seen utilizing a combination of transabdominal and transvaginal imaging with a partially filled bladder.

The uterine contour is optimally evaluated when the placenta is anterior, utilizing a partially filled bladder as the acoustic window. This marker, often referred as the 'placental bulge' can be seen both on transabdominal and transvaginal imaging. The bulge does not always reflect a 'through and through' defect of the uterine wall; rather it highlights the area of scar dehiscence and thinning of the myometrium in areas of PAS.[12,46,68] Although this finding has not been correlated specifically with increased morbidity or mortality, its presence raises the concern for extra-uterine placental extension (percreta). Color Doppler is often helpful to determine the extent of vascular invasion.

Bridging vessels are defined as vessel(s), identified on color Doppler, that extend from the placenta across the myometrium and/or beyond the uterine serosa. This has been considered one of the 'classic markers' of PAS over the years but has lacked consistency in its definition.[6,9] Typically seen running perpendicular to the long axis of the uterus, bridging vessels are often associated with the presence of a placental bulge with placental tissue extending beyond the uterine serosa.[41] Unlike other markers which can often be seen in cases without PAS, this marker is rarely seen in cases without PAS.[10]

It is important to note that the placenta is a three-dimensional structure and thus comprehensive sonographic assessment is required in at-risk pregnancies. This is best performed by obtaining several parasagittal and transverse planes of the placenta during the ultrasound examination. Special attention should be given to the retroplacental area and the lower-segment and cervical regions. This is best achieved with a combined transabdominal and transvaginal approach. Table 5 presents the sonographic approach in the second and third trimesters of pregnancy.

Discussion

This document, endorsed by AIUM, SMFM, ACR, and GOHO, supported by ACOG and ISUOG, approved by SRU, with ARDMS participating in the development and production of the document, presents a consensus-based approach to the ultrasound examination and assessment of PAS. Pregnancies with PAS are at significantly increased risk for maternal and fetal morbidity and mortality. Prenatal detection of PAS, reduces pregnancy complications and improves outcomes.[3,7,8,43] Several PAS markers have been identified and studied. There has been an effort to standardize the definitions of PAS markers, with the ultimate goal of improving risk stratification by ultrasound resulting in improved prenatal detection and thus positively impacting pregnancy outcomes. This task force, assembled by the SMFM with representation from multiple societies and organizations, provided definitions for PAS markers along with a standardized approach to the ultrasound examination in at-risk pregnancies.

It is important to recognize that the proposed definitions of PAS markers are based on the current literature, along with expert opinion when data are lacking. As ultrasound technology advances with improved tools, detection of abnormal placental invasion and vasculature should be greatly enhanced. Advancement in ultrasound technology may render the definitions of some existing PAS markers obsolete. An example is the current definition of abnormal placental vasculature. Emerging ultrasound technology has resulted in significant improvements in the sonographic detection of low velocity vascular flow. Accordingly, this may result in difficulty differentiating normal from abnormal placental flow.

It is also important to note that many of the markers presented in this document have been studied in women with prior cesarean deliveries and placenta previa.In women without these risk factors, however, the markers are seen often and typically in the absence of PAS.[10] As such, the recommended ultrasound approach to women without these risk factors remains largely unknown and is an area of great interest.

There are several limitations of ultrasound in detecting PAS. Ultrasound is an operator dependent imaging modality and thus is highly dependent on the skills of the examiner performing the ultrasound. The detection rates will depend on placental location as well as maternal imaging conditions which impact sonographic visualization of markers. A standardized approach to the performance of the ultrasound examination along with consensus-based definitions of PAS markers will result in more consistency in diagnosis and allows for evaluation of markers across centers in order to improve diagnostic performance. Despite optimizing a systematic approach to the ultrasound examination for PAS markers, inherent limitations of ultrasound may diminish detection rates. These include posterior placentation, with limited sound penetration and resolution, elevated maternal body mass index and uterine leiomyomata. The task force also identified research gaps for sonographic markers of PAS (Table 6). We hope that future research will use the definitions hereby provided along with a standardized approach to the ultrasound examination in order to facilitate data comparison. In addition, although the scope of this task force was focused on the ultrasound examination, we hope similar efforts are made in the future to provide guidance on the use of magnetic resonance imaging (MRI) for the evaluation of PAS.

As PAS has become more prevalent, the need for agreement on the definitions of ultrasound markers and sonographic approach to the at-risk patient is crucial. This document provides necessary steps towards consistency in the definitions of PAS markers and the approach to diagnosis. Accurate antenatal diagnosis is paramount in optimizing maternal and fetal outcomes. Further work will be needed to measure the impact of the proposed standardized definitions, along with the approach to the ultrasound examination.

Table 1: Task Force Participating Members and Societies

Alfred Abuhamad – SMFM, Co-Chair	Katherine M. Johnson – SMFM
Scott A. Shainker – SMFM, Co-Chair	Deborah Levine – SRU
Beverly Coleman – ACR	Joan Mastrobattista – AIUM
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SMFM – Society for Maternal Fetal Medicine, ACOG – American College of Obstetricians and Gynecologists, GOHO – Gottesfeld Hohler Memorial Society, ACR – American College of Radiologists, ISUOG – International Society of Ultrasound In Obstetrics and Gynecology, SRU – Society of Radiologists in Ultrasound, AIUM – American Institute of Ultrasound in Medicine, ARDMS - American Registry for Diagnostic Medical Sonography

Table 2: Definitions of PAS Markers in the First Trimester

Cesarean Scar Pregnancy- Gestational sac implantation in-part or totally within the cesarean scar -Gestational sac may have tear drop or triangular shape
Low Implantation Pregnancy- Gestational sac located close to the internal cervical os (up to 8 6/7 weeks of gestation) and/or placental implantation located posterior to a partially filled maternal bladder (up to 13 6/7 weeks of gestation)

Table 3: Approach to Ultrasound Examination in the First Trimester

-Transvaginal ultrasound is recommended in early pregnancy, and transabdominal ultrasound when appropriate -Detailed evaluation of the uterus in the migsagittal plane to document the gestational sac (up to 8 6/7 weeks of gestation) and/or the placental location (up to 13 6/7 weeks of gestation). Documentation should include reference to the position of the sac and/or placenta relative to the bladder, cesarean scar (if present), and the internal cervical os -Color Doppler using a low-velocity scale, low wall filter and high gain to maximize detection of flow (adjusting as needed for body habitus and other clinical factors).* -Evaluate shape of gestational sac (up to 8 6/7 weeks of gestation) - Imaging should be performed with a partially filled maternal bladder -The area of interest should be magnified so that it occupies at least half of the ultrasound image with the focal zone at an appropriate depth

* Color Doppler should be limited to the areas of interest and avoid the embryo/fetus whenever possible.

Table 4: Definitions of PAS Markers in the Second and Third Trimester of Pregnancy

Placental Lacunae
-Irregular, hypoechoic space(s) within the placenta containing vascular flow (which can be seen on gray scale and/or color Doppler) -The following lacunae findings are associated with high risk of PAS: - Multiple (often defined as ≥3) - Large size - Irregular borders - High velocity* and/or turbulent flow within
Abnormal Utero-placental Interface
-Loss of the retroplacental hypoechoic zone between the placenta and myometrium** - This marker is often located along the posterior bladder wall resulting in partial or complete interruption or irregularities of the utero-vesical interface -Thinning of the retroplacental myometrium (previously described as myometrial thickness of<1mm)
Abnormal Uterine Contour (placental bulge)
-Placental tissue distorting the uterine contour resulting in a bulge-like appearance
Exophytic Mass
-Placental tissue extruding beyond the uterine serosa
Bridging Vessel
-Vessel that extends from the placenta across the myometrium and beyond the uterine serosa

*some studies suggest >15cm/s as the threshold in the 2nd and 3rd trimester

**This space represents the uterine decidua and has been described as the "clear zone"

Table 5: Approach to Ultrasound Examination in the Second and Third Trimesters of pregnancy

Lacunae
- Detailed evaluation of the entire placenta in orthogonal planes - Lacunae should be evaluated using gray scale and color Doppler - Doppler assessment should generally be performed with a low-velocity scale, low wall filters and high gain to maximize detection of flow* (adjusting as needed for body habitus and other clinical factors)
Abnormal utero-placental interface
- Evaluation of the utero-placental interface is optimized by perpendicular orientation of the transducer to the area of interest with minimal transducer pressure - Transvaginal ultrasound is recommended in the setting of an anterior, low-lying placenta or placenta previa - Imaging should be performed with a partially filled maternal bladder - Optimization of gain settings to help differentiate between placental and myometrial tissue - The area of interest should be magnified so that it occupies at least half of the ultrasound image with the focal zone at appropriate depth - Myometrial measurement should be made perpendicular to the long axis of the uterus and measured at the thinnest site (commonly along the uterine scar)
Abnormal Uterine Contour
- Placental tissue distorting the uterine contour resulting in a bulge-like appearance (this is best appreciated in a midsagittal plane of the uterus)

Exophytic Mass
-Placental tissue visualized beyond the uterine serosa
Bridging Vessel
-Doppler assessment of vessels extending from the placenta across the myometrium and beyond the uterine serosa[**]

*some studies suggest >15cm/s as the threshold for high peak systolic velocity

**These need to be differentiated from bladder varicosities which are not placental in origin and do not increase risk of PAS

Table 6: PAS Ultrasound Marker Research Gaps

-What is the utility of TVUS 1st trimester screening in all women with prior cesarean delivery?
-What is the appropriate timing of 1st trimester screening in women with prior cesarean delivery?
-Does location, size, and number of lacunae predict extent of invasion?
-How to define "high" peak systolic velocity in lacunae?
-Are the vessels resulting in uterovesicular hypervascularity placental or maternal in origin?
-What is the significance of increased placental thickness?
-Need to clarify the role of vascular imaging with newer technologies.
-What is the role of 3D ultrasound to assess: placental volume, exophytic masses, bridging vessels?
-How to define and assess cervical hypervascularity?
-How do PAS ultrasound markers correlate with maternal biomarkers?
-Define how placental ultrasound markers progress with advancing gestational age?
-Determine the role of MRI in the evaluation of PAS?

Abbreviations: MRI, magnetic resonance imaging; PAS, placenta accreta spectrum; TVUS, transvaginal ultrasound

Figure titles and captions:

Figure 1: Placenta Lacunae

Gray-scale imaging of placenta lacunae (*) in the setting of placenta previa with PAS.

A: transvaginal midline-sagittal image

B: transabdominal midline-sagittal image

Figure 2: Retroplacental Hypoechoic Zone

Transvaginal midline sagittal gray-scale imaging of placenta previa:

A: normal appearing retroplacental hypoechoic zone (arrows)

B: abnormal/loss of the retroplacental hypoechoic zone (arrows) in PAS

Figure 3: Myometrial Thinning

Transabdominal midline sagittal gray-scale from a patient with focal PAS.

Area of normal myometrial thickness (asterisks) compared to areas of thin myometrium. (arrows)

Figure 4: Hypervascularity of the utero-vesical space

Transabdominal midline sagittal ultrasound in gray scale (A) and color Doppler (B) of PAS demonstrating hypervascularity of the utero-vesical space. Note the presence of a large blood clot (asterisk) in the lower uterine segment

Figure 5: Utero-placental interface

Transvaginal midline sagittal imaging of placenta previa with PAS

A: gray-scale imaging demonstrating irregularities along the utero-placental interface (arrows) and bulging of the lower uterine segment into the bladder (Asterisk)

B: color Doppler highlighting hypervascularity within the utero-placental interface

Figure 6: Abnormal uterine contour and bridging vessel

Transabdominal midline sagittal ultrasound image of placenta previa with PAS

A: gray-scale imaging of abnormal uterine contour with bulging of the lower uterine segment (small arrows) into the posterior bladder wall and interruption of the bladder wall (large arrow).

B: Color Doppler imaging demonstrating bridging vessel at the site of bladder wall interruption (large arrow)

Figure 7: Cesarean Scar Pregnancy

Transvaginal midline sagittal ultrasound in gray-scale demonstrating a cesarean scar pregnancy (A). Note the teardrop shape of the gestational sac (A) in close proximity to an empty bladder (B) and touching the internal cervical os (arrow) of the cervix (C).

Figure 8: Cesarean Scar Pregnancy

Transvaginal ultrasound in gray scale (A) and color Doppler (B) of a cesarean scar implantation (arrow) and bulging of bladder line (arrow head).

Figure 9A: Low Implantation Pregnancy

A: Transvaginal ultrasound at 11 weeks' gestation in gray scale in a pregnancy with low implantation of the gestational sac. Note that the placenta is covering the internal os (arrow) of the cervix (C).

Figure 9B: Low Implantation Pregnancy

B: Transvaginal ultrasound at 11 weeks' gestation in color Doppler in a pregnancy with low implantation of the gestational sac (same as in Figure 9A). Note the presence of extensive vascularity extending into the cervix (C).

Figure 10: Abnormal uterine contour

Transabdominal midline sagittal ultrasound with extended view of a pregnancy with PAS. Note the presence of placental bulge and thickening in the lower uterine segment (arrows) and into the bladder (B). Double arrows compare the placental thickness in the upper and lower segment of the uterus.

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