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Role of CrystalVue™ and MV-Flow™ with LumiFlow™ in the prenatal diagnosis of Placenta Accreta Spectrum

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Introduction

Placenta accreta spectrum (PAS), previously known as abnormally invasive placenta (AIP), encompasses a group of disorders characterized by an abnormally deep invasion of the placental trophoblasts into the myometrium or into the organs surrounding the gravid uterus. The rising rate of cesarean section together with the increased maternal age and use of assisted reproductive techniques are accounted as major determinants of the increased frequency of PAS, which is currently reported to range between 1:300 and 1:2000 pregnancies[1-6]. PAS is acknowledged to represent a major risk factor for pregnancy and peripartum complications including potentially life-threatening hemorrhage requiring emergency hysterectomy and blood transfusion. In such context, the antenatal characterization of the placental location and the risk of PAS has been demonstrated to improve multidisciplinary care management and surgical planning, ultimately leading to reduced maternal peripartum morbidity.

The latest guidelines of the International Federation of Gynecology and Obstetrics (FIGO)[7] acknowledge that the most common risk factors for PAS are represented by the combination of the finding of placenta previa in the current pregnancy and a history of previous cesarean section. More specifically, the guidelines recommend that all women carrying such combination of risk factors "should be referred to a center with expertise in the prenatal diagnosis of PAS disorders"[7].

Prenatal ultrasound represents the primary tool for the prenatal detection and risk stratification of PAS, and evidence from a systematic review and meta-analysis has shown that prenatal ultrasound in expert hands has an excellent accuracy in the identification of PAS disorders. Nonetheless, several studies have shown a considerable variability in reporting of the performance of 2D and 3D ultrasound[8] in the diagnosis of PAS disorder, and population-based studies have demonstrated that PAS disorders are undetected in at least half of the cases[9-10]. This may result from the absence of recommendations detailing how to systematically evaluate the patient at risk for PAS with ultrasound and the lack of referral centers with expertise in the diagnosis and management of PAS disorders. Also, this may result from the inconsistencies across studies, often retrospective in their design, in terms of lack of standardization of the ultrasound (US) markers, of the different approaches adopted for the imaging of the patient at risk for PAS disorder, and by the "a priori" risk of PAS disorder impacts on the clinical significance of the US indicators of PAS[11-12].

With respect to the standardization of ultrasound imaging in women at risk for PAS disorder, a recent consensus statement issued by the Society for Maternal Fetal Medicine (SMFM)[12] has revised the definitions of the ultrasound markers which can be evaluated with two-dimensional ultrasound in the second and third trimesters of pregnancy to include the presence of intraplacental lacunae, the loss of the retroplacental hypoechoic (clear) space, and the abnormality of the uterus-bladder interface representing the most commonly evaluated.

In this context, the SMFM consensus statement and the FIGO guidelines acknowledge that ultrasound technologies, including three-dimensional rendering and Doppler, may add in the expert assessment of the patient at risk, thus contributing to the variable performance of prenatal ultrasound in detecting and characterizing PAS disorders.

With regards to the most recently described ultrasound signs, in 2018 our research group described the 'tramline sign' and its association with intraoperative or pathology findings in women at risk for PAS based on an anterior placenta previa[13]. The tramline sign is described as the tramline-like appearance of the normal bladder mucosa/uterine myometrial interface which, under normal circumstances, is not interrupted. In detail, the sign can be assessed starting from three-dimensional ultrasound volumes acquired either transabdominally or transvaginally and processed on the ultrasound monitor using the built-in, post-processing CrystalVue™ and CrystalVue Flow™ software[14-19]. With the render direction set to A+, the assessment of the interface across the entire width of the bladder mucosa can be achieved by moving the region of interest (ROI) in the sagittal plane from left to right, in which the ROI line is perpendicular to the mucosal/myometrial interface with the bladder vertically above the uterus. A prospective two-center study led by our research group demonstrated the strong relationship between the tramline-like appearance of the uterine-bladder interface and the perioperative outcomes including surgical complexity and need for transfusion in women at risk for PAS.

As described in our previous research, the ROI box was made to demonstrate as thin a slice as possible. The tramline was only then visible. The tramline was described as normal or partially/fully interrupted.

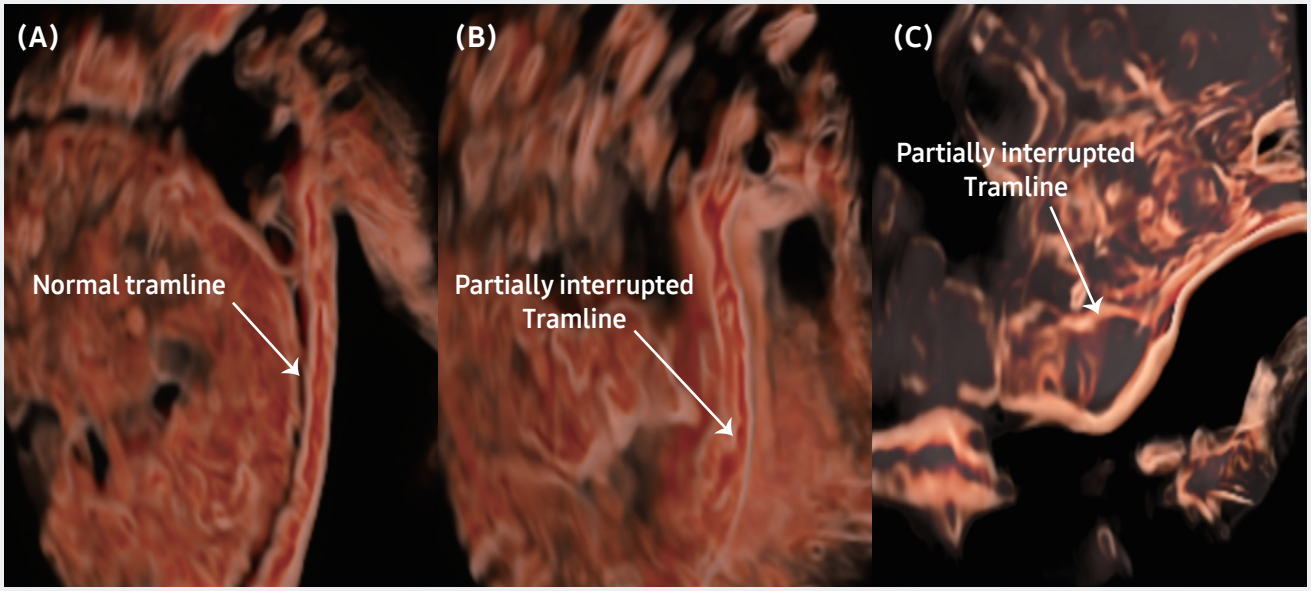

Figure 1. 3D transvaginal ultrasound images obtained using a 1.0–8.0 MHz 3D/4D curved array transducer (CV1-8A HERA W10, SAMSUNG MEDISON, Co., Ltd, Seoul, Korea) and rendered using RealisticVue™ and CrystalVue™.
(A) RealisticVue™ and CrystalVue™ image demonstrating 'Normal tramline' suggesting no evidence of PAS. **(B)**, **(C)** RealisticVue™ and CrystalVue™ image demonstrating 'partially interrupted tramline', which was associated with a postnatal diagnosis of PAS.

The identification of abnormal hypervascularity and complex vascular networks in the placenta, the parametrium and the uterovesical interface have also been suggested to improve the predictive potential of ultrasound[20]. MV-Flow™ and LumiFlow™ are newly developed Doppler technologies capable of providing a detailed view of the blood flow in relation to surrounding tissue as an alternative to power Doppler for the visualization of slow flow microvascularized structures and vascular connections. MV-Flow™ technology is characterized by high tissue suppression to reduce tissue noise signals, suppression of flash artifacts (due to its advanced filter), compound images, and high sensitivity; all of which contribute to optimizing the imaging of low velocity flow structures. LumiFlow™ helps to display the structure of blood flow and small vessels intuitively, giving a three-dimensional visualization of the blood flow in a two-dimensional image. This high-resolution feature is available in combination with all Doppler technologies allowing a more realistic assessment of the vascular flow. Such technologies could aid the imaging of the vascular networks in the uterovesical interface, the parametrium, and the placenta, including the 3D-derived 'tramline' sign.

Methods and results

In this work, we describe the placental imaging features obtained with CrystalVue™ and MV-Flow™ technology combined with LumiFlow™ in women referred with suspected PAS. In detail, we propose a descriptive methodology for the diagnosis of PAS. CrystalVue™, MV-Flow™ and LumiFlow™ are built-in, commercially-available software installed on the high-resolution ultrasound system HERA W10 (SAMSUNG MEDISON, Co., Ltd, Seoul, Korea).

The 3D technique involves obtaining transabdominal 2D views of the utero-placental interface by scanning the uterus longitudinally with partially full bladder to examine the location of the leading edge of the placenta relative to the internal cervical os, the utero-placental interface (the clear zone), the appearance of the uterovesical interface and bladder wall, and the appearance of the placenta (lacunae). MV-Flow™ and LumiFlow™ are then applied to the image to map the vasculature along the myometrial-bladder interface. When MV-Flow™ is activated, it provides modified acquisition settings for low PRF (pulse repetition frequency) and high resolution. It improves diagnostic confidence by obtaining high resolution microvascular flow. LumiFlow™, by providing 3D visualization of microvasculature, provides improved identification of signs such as uterovesical hypervascularity, bridging vessels, and placental lacunae feeder vessels, which are color Doppler signs described by FIGO[10].

3D ultrasound volumes are acquired transabdominally with the myometrial-bladder interface in sagittal view, using an appropriately sized sample volume. 'Extreme scan' quality settings are ideally used to acquire the volumes. Of the 5 scan quality settings, 'extreme scan' results in the slowest acquisition time, but gives the highest resolution of the volume dataset. The 3D volume consists of 3 orthogonal planes are that are at right angles to each other. The 3D volumes are then subjected to post-processing using both RealisticVue™ and CrystalVue™. We use 'surface render mode' as a preset, which gives a more textured appearance to the rendered anatomy.

The thinnest Region Of Interest (ROI) is used and High Definition Volume Imaging (HDVI), which once activated, offers 5 levels of optimization, is selected to optimize the rendered view. The MPR (Multi-Planar Reconstruction) screen also offers the option to select HDVI types. There we choose 'Face' as our preferred HDVI option type, which in our experience, offers maximum details in evaluating the myometrial-bladder interface.

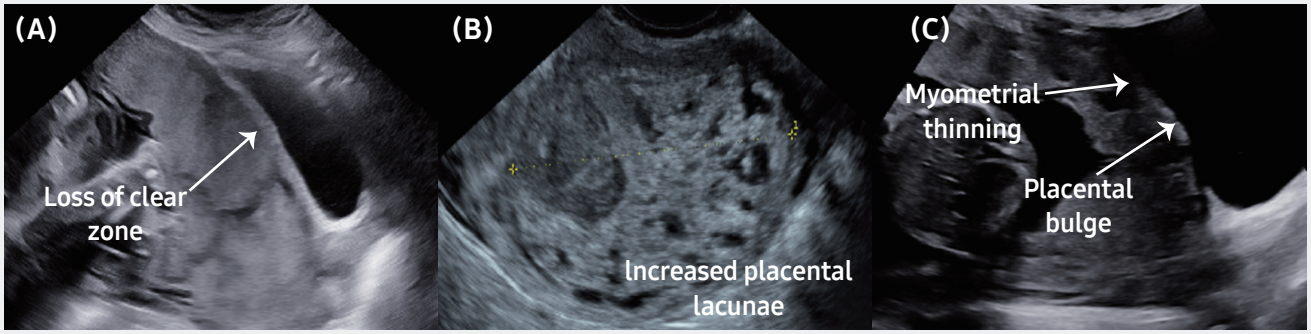

Figure 2. Transabdominal ultrasound images depicting 2D US signs of PAS. Images obtained using a 1.0–8.0 MHz 3D/4D curved array transducer (CV1-8A, HERA W10, SAMSUNG MEDISON, Co., Ltd, Seoul, Korea).
(A) 2D image showing major placenta previa with 'loss of clear zone' at the level of the uterine-placental interface. **(B)** 2D US image showing large and vascular placental lacunae. **(C)** 2D US image depicting irregular uterovescical interface with thinned myometrium and irregular uterine-bladder interface with placental bulge, which are signs of PAS.

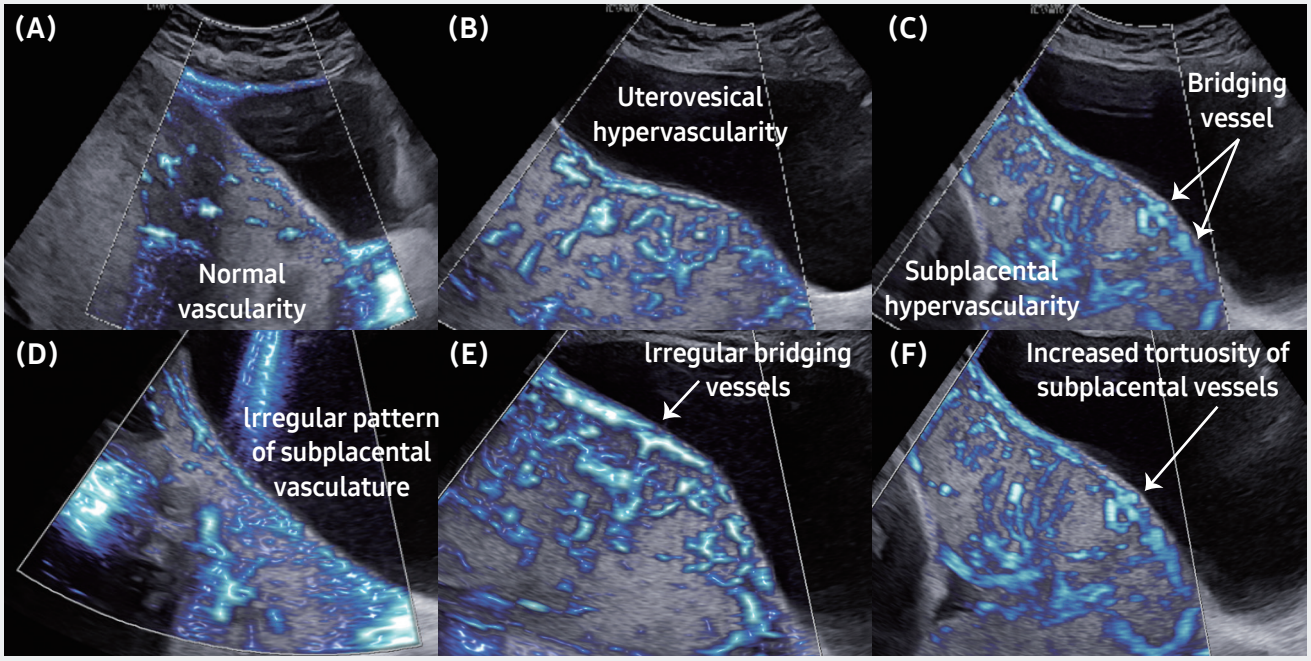

Figure 3. MV-Flow™ and LumiFlow™ imaging in patients at risk for PAS. Transabdominal images obtained using a 1.0–8.0 MHz 3D/4D curved array transducer (CV1-8A, HERA W10, SAMSUNG MEDISON, Co., Ltd, Seoul, Korea).
(A) MV-Flow™ and LumiFlow™ technique in a case of major placenta previa at low risk for PAS, with no PAS as confirmed at cesarean section. **(B)** MV-Flow™ and LumiFlow™ demonstrating increased tortuosity and uterovesical hypervascularity in a case of placenta previa with postnatal confirmation of PAS. **(C)** MV-Flow™ and LumiFlow™ demonstrating increased subplacental hypervascularity and bridging vessels in a case of placenta previa with PAS confirmed at cesarean section. **(D)** MV-Flow™ and LumiFlow™ demonstrating irregular pattern of the subplacental vasculature, **(E)** bridging vessels and **(F)** increased tortuosity of the subplacental vessels in a case with postnatally diagnosed PAS.

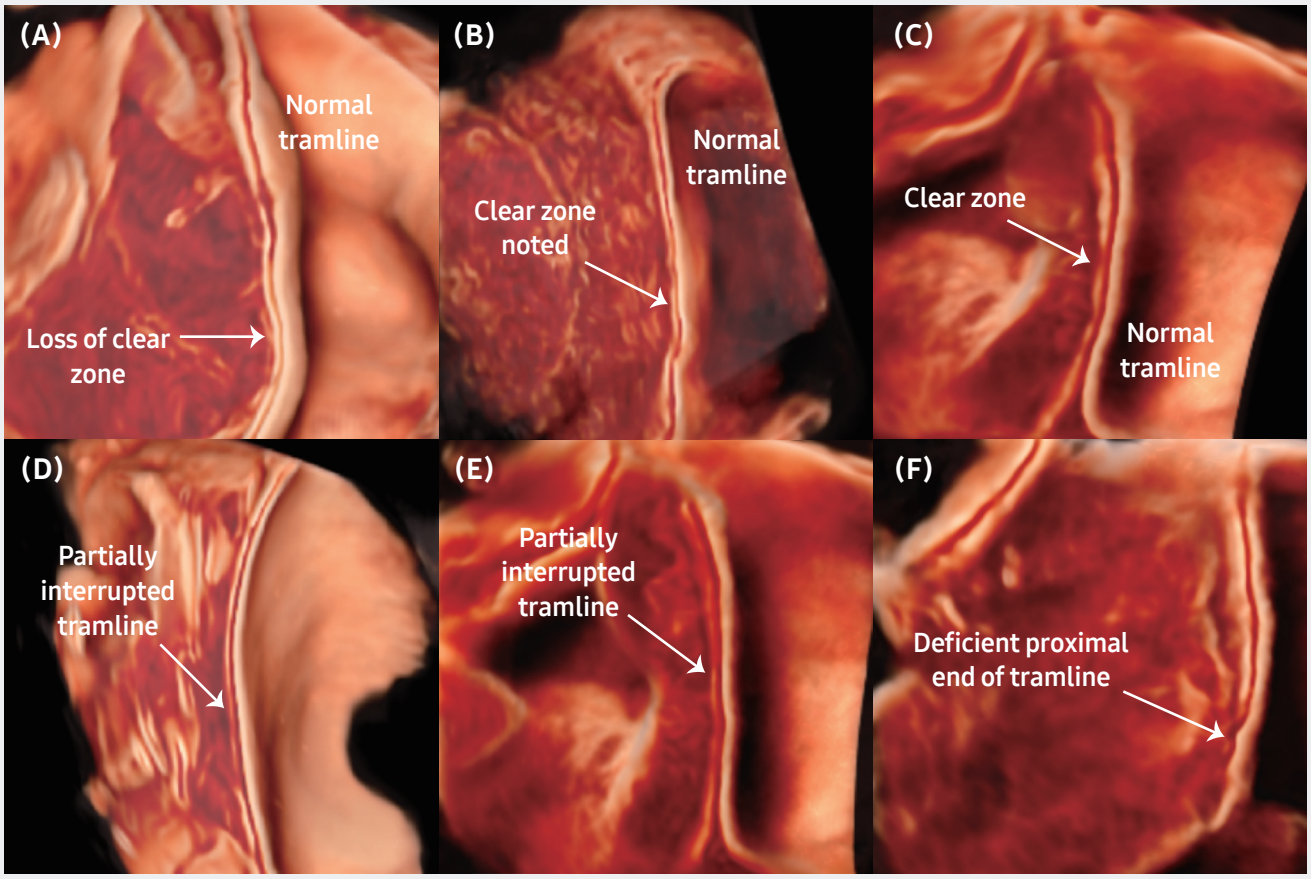

Figure 4. 3D transabdominal ultrasound images obtained using a 1.0–8.0 MHz 3D/4D curved array transducer (CV1-8A, HERA W10, SAMSUNG MEDISON, Co., Ltd, Seoul, Korea) and rendered with RealisticVue™ and CrystalVue™.
(A) RealisticVue™ and CrystalVue™ image demonstrating the co-existence of the 'loss of clear zone' and a 'normal tramline' in a case of major placenta previa focally and superficially invading the myometrium at cesarean section. **(B,C)** 'Normal tramline' with presence of the 'clear zone' in a case of placenta previa with clinical evidence of PAS. **(D,E,F)** Partially interrupted tramline in three cases with PAS confirmed at cesarean section.

Conclusion

While 2D ultrasound can delineate extrauterine spread in PAS, the placenta-myometrial interface is best assessed using MV-Flow™ and LumiFlow™ which allows vascular assessment. The myometrial/placenta and vesicular border is best evaluated by means of the tramline sign, which can be obtained from a 3D volume post-processed and rendered using CrystalVue™ and RealisticVue™. Our experience has shown that 2D imaging, together with MV-Flow™ and LumiFlow™, and 3D volume post-processing with CrystalVue™ and RealisticVue™ are a multimodality, easy-to-use, sequential technique in the diagnosis of PAS. This technique enables a comprehensive assessment of the placenta, myometrium and bladder that allows different and complementary imaging techniques to be used to support the clinical management of the patient at risk for PAS.

Supported Systems

- HERA W10

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