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Opinion

Hidden in plain sight: role of residual myometrial thickness to predict outcome of Cesarean scar pregnancy

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Introduction

Cesarean scar pregnancy (CSP) is defined as the low, anterior uterine implantation of a fertilized oocyte, which develops into a gestational sac at the site of a scar resulting from a previous Cesarean delivery (CD). CSP is not a singular condition but rather a spectrum of clinical phenotypes, the severity of which can be characterized according to the spatial relationship between the gestational sac, the area of the CD scar and the anterior uterine wall. The pregnancy may implant 'on the scar' (Type 1) or deep 'in the niche' (Type 2)[1]. The latter is associated with a lower residual myometrial thickness (RMT) and a higher risk of uterine rupture, significant bleeding and progression to severe forms of placenta accreta spectrum (PAS) disorder, such as placenta percreta. Conversely, implantation 'on the scar' carries a lower risk of adverse maternal outcome and is characterized by a higher RMT, which accounts for the reduced occurrence of severe complications.

The natural history of CSP has been partially elucidated in recent years. Although the majority of cases are characterized by spontaneous resolution, those continuing through the first trimester of pregnancy may, in about 10% of cases, experience severe uterine complications, including severe hemorrhage, uterine rupture and need for hysterectomy. Those pregnancies not experiencing such outcomes mostly continue through the second and third trimesters as PAS disorders, for which CSP is now considered an early precursor. In view of its association with significant maternal morbidity and even mortality[2,3], regardless of management, CSP is considered a high-risk condition and treatment is commonly offered to patients. The first challenge in the management of CSP is accurate diagnosis and classification. The second is patient counseling regarding clinical outcome. Both diagnosis and counseling are informed by various non-sonographic (clinical and history) and sonographic markers. Each of these markers carries a different weight in the prognostication of outcome. The diagnostic value of these markers in the early first trimester is well known. It seems that one such marker, namely the thickness of the myometrium at the depth/tip of the niche left by the prior CD, has a notable role in determining the outcome of the pregnancy. This marker can be quantified, and its measurement can be used in clinical practice when counseling patients about management.

The aims of this Opinion were to review the available clinical data on the role of RMT in predicting the outcome of expectantly managed or even treated CSP and to evaluate its clinical applicability. We offer an up-to-date summary of the clinical evidence on RMT as a measurable and objective ultrasound marker and touch on other sonographic markers of CSP.

Anatomy of post-Cesarean delivery niche

There is now an extensive body of literature describing the anatomy of the post-CD niche. The first description of the post-CD niche, including its formation, sonographic appearance and dimensions, was in a study of 44 patients reported by Monteagudo *et al.*[4] in 2001, which also contains the first recorded use of the term RMT. A filling defect or 'niche' was defined as a triangular anechoic structure at the presumed site of a scar from a previous CD. The depth and mean RMT of the niche were measured. The sighting of two simultaneous niches following two CDs was also reported.

To clarify the nomenclature used, we include here a histological specimen of a uterine niche, annotated with the key anatomical features relevant to this discussion (Figure 1a). The components of the CD niche can be recognized easily on imaging, especially when using two-dimensional (2D) or three-dimensional (3D) transvaginal ultrasound (TVS) (Figure 1b,c). A relatively large niche in which the RMT can be measured is depicted in Figure 1b; however, probably due to the depth of the niche, the adjacent myometrial thickness (AMT) equals the thickness of the anterior uterine wall. The same issue is evident in the TVS image of a 6-week Type-2 CSP with a thin RMT, in which the AMT was impossible to define (Figure 1c).

In two descriptive articles dedicated to uterine niches in non-pregnant patients, the RMT was discussed in detail[5,6]. The authors suggested that RMT and AMT should be measured in the sagittal plane of the uterus, and that the smallest RMT should be reported. The authors also included an optimal cut-off value for the RMT. They concluded that only basic measurements, such as niche length and depth, RMT and AMT in the sagittal plane and niche width in the transverse plane, should be considered essential.

It is the authors' experience that while it may be easy to measure the AMT in the non-pregnant woman, this parameter is hard to detect and measure in the first trimester of a CSP, when the enlarging gestational sac progressively occupies the niche and the RMT becomes identical to the actual anterior uterine wall.

Markers of CSP

The most appropriate time window in which to diagnose, stratify and predict the prognosis of CSP is the early first trimester, preferentially between 6 and 10 weeks' gestation[7]. The reasons are twofold. First, the diagnosis of CSP is based on the identification of the gestational sac within or in close proximity to the area of the CD scar. This relationship is better assessed in the early part of the first trimester. With advancing gestation, the upper pole of the gestational sac grows towards the uterine fundus, making assessment of this relationship more challenging. Second, treatment for CSP is technically more feasible and associated with a lower burden of perinatal complications in the first trimester. This is likely because CSP, in its early stage, is associated with microvascular invasion of the surrounding myometrium. With advancing gestation, the release of vascular growth factors leads to the development of a massive and aberrant vascular network, which is responsible for the severe hemorrhagic events observed in CSP and PAS disorders.

Below is a list of non-sonographic and sonographic markers used clinically in the diagnosis of CSP, with a short commentary on their relevance and clinical utility.

Previous Cesarean delivery. This is a *sine qua non* of establishing a diagnosis of CSP[5]. Extremely rarely, myomectomy may be a cause[8].

Anteverted retroflexed uterus. This should be considered a supportive marker that, when present, corroborates the diagnosis, since about 27% of uteri assume this position after CD[9,10].

Low/anterior position of gestational sac. Two interpretations of this marker should be considered. The first involves dividing the uterus perpendicularly to the longitudinal axis on a sagittal ultrasound image into an upper

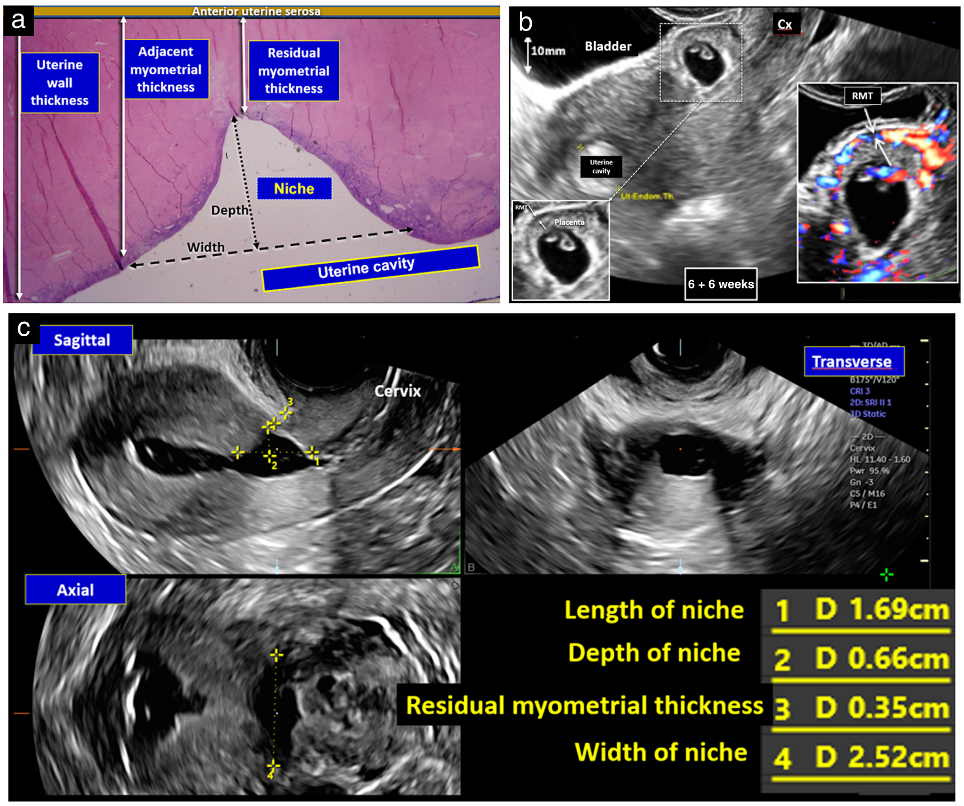

Figure 1 Anatomy of post-Cesarean delivery niche. (a) Histology specimen of niche on which clinically relevant measurements are superimposed. (b) Grayscale ultrasound image of Cesarean scar pregnancy at 6 + 6 weeks' gestation, depicting measurement of residual myometrial thickness (RMT) in two enlarged inlays. (c) Three-dimensional ultrasound image of uterus with niche, demonstrating customary niche measurements in addition to measurement of RMT. Cx, cervix.

and a lower half and locating the center of the gestational sac. If the center of the gestational sac is below the dividing line (the 'midpoint axis') and close to the anterior wall and the internal cervical os, it is likely to be a CSP[7,11]. The second method was suggested by Calì *et al.*[12], who divided the uterus lengthwise on a sagittal ultrasound image. A gestational sac in front of/above this so-called 'endometrial line' and closer to the anterior serosal surface of the uterus was indicative of CSP.

Embryonic/fetal heart activity. The presence or absence of cardiac activity in the embyro/fetus within a low, anterior gestational sac is a significant finding for counseling and clinical management[7].

Low/anterior placental location. This marker is relevant once the placenta has developed to a sufficient size to be visible sonographically. Once reliably detected, its implantation over the CD scar or its niche, close to or over the internal os, becomes an important ultrasound marker. Moreover, first-trimester placenta previa is a powerful supporting finding for the presence of CSP. Lacunae are detected increasingly from 6–7 weeks onward and likewise support the diagnosis[7,13].

Increased peritrophoblastic vascularity. This marker is detected progressively using color Doppler imaging, especially microvascular color Doppler, but is hard to quantify and usually evaluated subjectively[5]. However, Jauniaux *et al.*[14,15] evaluated the utero- and intraplacental vasculature at 6–10 weeks using color Doppler imaging and described a semiquantitative score from 1 to 4.

Thin or no RMT between gestation/placenta and anterior uterine contour at level of scar. Since this is the main focus of this article, the measured values of RMT published in the literature and their practical use in predicting CSP outcome are discussed in detail below.

It is important to mention that, despite their clinical relevance, there is still a relative paucity of data on the association between the abovementioned ultrasound signs and the occurrence of adverse outcome in CSP. Conversely, RMT has been reported on more widely by experts of CSP and PAS. This may be due to the fact that clinicians in this field were influenced by their own experience in diagnosing and managing CSP, so favored a measurable marker (i.e. RMT), considering it more useful than other markers.

It seems, based on our multi-institutional experience, as well as the direct and indirect references in the literature to the use of RMT in diagnosing and managing the first-trimester CSP, that there is a need to address the different aspects of this crucial marker of placental adherence pathology, such as how it changes with advancing gestation. This marker may be even more relevant if a CSP is continued and 'morphs' into second- and third-trimester PAS disorder.

Although the number of published studies on the uterine niche has increased in recent years, there is no uniform, internationally recognized definition or guideline for niche evaluation. Naji *et al.*[16] proposed a standardized method for identifying a niche with ultrasonography, which involved classifying the appearance of a niche based on its clinical value (mild, moderate or severe scar defect) and performing measurements in three dimensions (length, width and depth), as well as measuring RMT. Measurements were not further defined or specified for different niche shapes, for example in the presence of a branch or fibrotic tissue at the site of the uterine scar. The group of Prof. Huirne devoted several articles to the subject of post-CD uterine niches, of which two that are pertinent to this article were mentioned previously[5,6]. Tower *et al.*[17] proposed a classification of niches based on RMT and the RMT/AMT ratio as the only ultrasonographic features.

Practical use of RMT

A large number of articles in the literature on niche formation focus on evaluating the RMT after closure of the CD incision by various techniques, mainly in non-pregnant women. Since we intended to concentrate only on the RMT of the niche in cases of CSP, these publications were not included in our review. Similarly, we found many articles addressing the indications for surgical correction of uteri with a deep niche and thin RMT. Again, since they did not add value to our article, we stopped short of devoting space to them. However, we became acutely aware that these categories of excluded publication were targeting our object of interest: the RMT. This strengthened our belief in its importance and clinical utility, not only because it is used to assess the risk of uterine rupture in a subsequent pregnancy, but also because it is central to the development of a CSP in the depth of a niche.

There is further indirect proof that the RMT is a significant predictor of CSP outcome. We have already mentioned three first-trimester sonographic markers of CSP, which are based fundamentally on the RMT, and concern the positioning of the gestational sac: below the midpoint axis[11]; in front of the endometrial line[12]; or deep within the niche of the previous CD[1] (i.e. Type-2 CSP). In all three, the RMT between the gestational sac/placenta and the anterior uterine border is thin or non-existent. We combined these three early first-trimester diagnostic algorithms into a practical and easy-to-use method to classify CSP and predict later PAS, integrating first-trimester CSP assessment into the ultrasound staging of PAS disorders, naming the combined strategy the 'anterior-inferior PAS risk triangle' of CSP implantation[18].

Sonographic measurement of RMT

Based on evidence gathered from the literature and the authors' decades-long clinical experience, below is the suggested technical methodology to measure the RMT in patients with suspected CSP. Of note, the residual myometrium is a thin structure so, when measuring the RMT, a fraction of a mm could be significant (Figure 2).

- The best images are obtained using grayscale and TVS probe; a transabdominal probe may also be used, but will produce images with less detail and measurements will be less precise.
- A partially full bladder (about 200–300 mL) facilitates clear depiction of the area of interest between the bladder and anterior uterine border, without compromising patient comfort. The amount of urine in the bladder could also be about 2–3 cm on an anterior–posterior 2D image.
- The higher the frequency of the probe, the higher the resolution and hence the higher the accuracy of the measurement. We use a 6–12-MHz transvaginal probe that produces a high-resolution image and enables precise measurement.
- The focal range should be placed closer to the tip of the probe on the screen to include the area of interest and obtain a clear picture. This becomes even more important if a very high-frequency TVS probe is used.
- Care should be taken to avoid undue pressure of the probe on the bladder, since it may 'squeeze' the tissues and alter the RMT measurement.
- After obtaining and recording the best sagittal ultrasound image of the uterus, the area of interest should be enlarged, concentrating on the actual site of the border between the placenta/gestational sac and the bladder wall (Figures 1–3).
- On the sagittal image obtained, three measurements should be made on three successive frozen images, spanning the thinnest part of the myometrium and avoiding inclusion of the bladder wall and the placenta in the measurement. Color and/or microvascular color Doppler mode can help to identify and confirm that the space is indeed myometrium, with its thin, integral blood vessels, and not of placental origin. Alternating between grayscale and color Doppler increases the reliability of RMT evaluation and measurement (Figures 4 and 5).
- At times, the sac is not positioned symmetrically in the midline. This may become evident on turning the transducer from the sagittal to the transverse plane to reveal the ultrasound image of the low, anterior uterine area (Figure 6). The RMT should be evaluated by making several measurements, of which the thinnest should be reported (lower right panel in Figure 6).
- Transducer pressure should be eased, regardless of the sonographic approach, and the transducer should be shifted right and left in the sagittal plane and up and down in the transverse plane to obtain the best picture, which in fact is the thinnest RMT (Figure 4).
- Color Doppler should be used, with one's preferred display (e.g. radiant flow, microvascular color Doppler), while shifting through several sagittal and transverse planes, to evaluate myometrial vascularity between the placenta and the bladder/anterior uterine border (Figure 5).
- It is useful to attach a representative ultrasound image to the report, illustrating the method used to measure the RMT of the case.

The difference between the two major implantation types of CSP, namely Type 1 (on-the-scar implantation) and Type 2 (in-the-niche implantation), is summarized by schematic diagrams and sonographic images in Figures 7 and 8. We include also a case of Type-2 CSP diagnosed at 11 weeks (Figure 9). Serial follow-up scans to 14 + 6 weeks demonstrated progressive thinning of the myometrium and reduction in RMT. The CSP was implanted in a deep niche of the previous CD, which

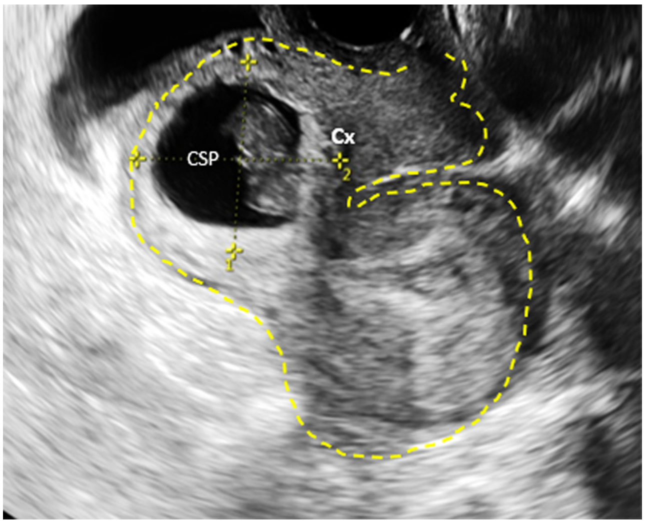

Figure 2 Grayscale ultrasound image of Cesarean scar pregnancy (CSP) at 9 + 5 weeks' gestation in anteverted retroflexed uterus (dashed line) with practically no measurable residual myometrial thickness. Cervix (Cx) is in anteverted position while uterine body with its empty cavity is retroflexed. No intervening myometrium is seen between decidua of gestational sac and bladder.

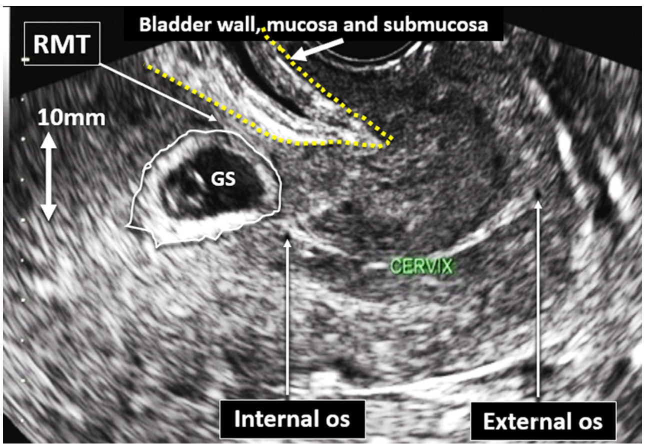

Figure 3 Grayscale transvaginal ultrasound image of Cesarean scar pregnancy, showing enlarged area of cervix and of internal os below bladder (dashed line). Residual myometrial thickness (RMT) between bladder wall and gestational sac (GS) is indicated.

developed into a large dehiscence with no measurable RMT between the scar and anterior uterine border. Successive TVS images throughout the first and early second trimester confirmed the finding. Due to danger of rupture, a hysterotomy followed by subtotal hysterectomy was performed. The paper-thin anterior cover was visible on the uterine specimen (Figure 9f). The patient required massive blood transfusion and blood products.

Literature review

There is no universal definition of RMT at the level of a CD scar. Some studies use terminology such as 'thinning of the myometrium' or 'triangular defect in the myometrium contiguous with the endometrial cavity', identified using TVS with or without saline contrast in non-pregnant as well as pregnant patients[17]. Ofili-Yebovi *et al.*[19] described deficient myometrium as 'myometrial thinning at the Cesarean section site', defining it in relation to the adjacent myometrium. They considered the RMT as thin if it was ≤ 50% of the AMT. Vikhareva Osser and Valentin[20] defined a remaining (residual) myometrial thickness of ≤ 2.2 mm on TVS as thin.

At the time of writing, searching for the term 'residual myometrial thickness' using the PubMed search engine retrieved 113 entries. Upon attempting to classify these articles, we found significant overlap and assigned some to more than one category. In general terms, 28 articles reported on repairing the niche after CD and 26 evaluated techniques of CD incision closure and their consequences on niche formation. There were seven systematic reviews, six articles devoted to diagnostic issues, 24 dealing with etiology, 17 reporting on the use of RMT in treatment and 20 on its prognostic value regarding

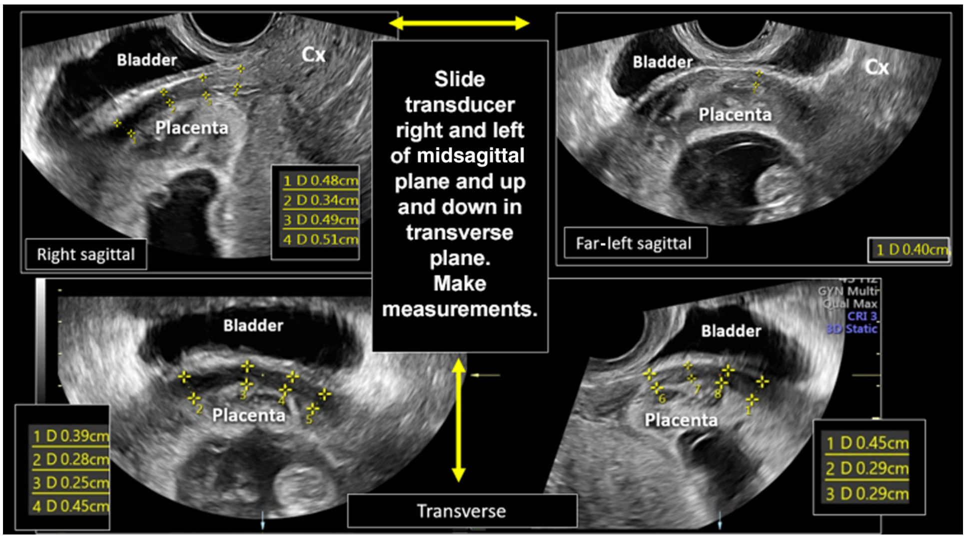

Figure 4 Grayscale transvaginal ultrasound images of Cesarean scar pregnancy, demonstrating importance of shifting vaginal probe right and left of midsagittal plane as well as up and down in transverse plane to obtain best measurement of residual myometrial thickness. Cx, cervix.

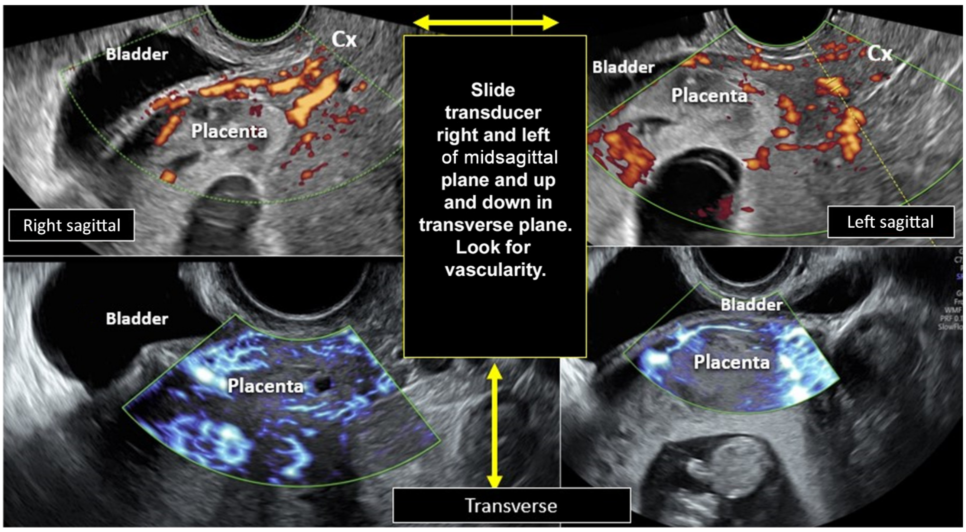

Figure 5 Transvaginal ultrasound images very similar to those in Figure 4, but with color Doppler mode turned on to evaluate quality and density of placental blood vessels in area between bladder and gestational sac. Cx, cervix.

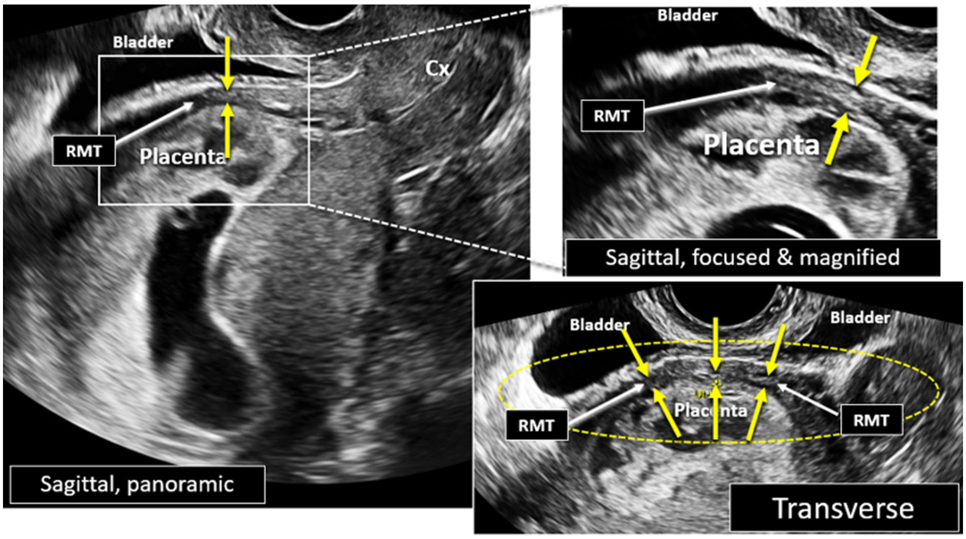

Figure 6 Grayscale transvaginal ultrasound images of Cesarean scar pregnancy, demonstrating importance of image enlargement. Sagittal panoramic image shows thin myometrial layer between placenta and bladder, where residual myometrial thickness (RMT) should be measured. Magnified sagittal image enables more precise measurement of RMT, which should be confirmed by measurement in transverse view. Cx, cervix.

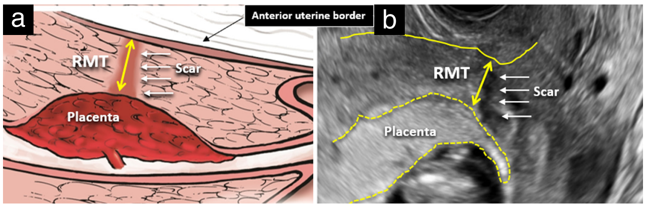

Figure 7 Schematic diagram (a) and grayscale transvaginal ultrasound image (b) of Type-1 Cesarean scar pregnancy (implanted 'on the scar'), showing thick residual myometrial thickness (RMT) between placenta and anterior uterine border.

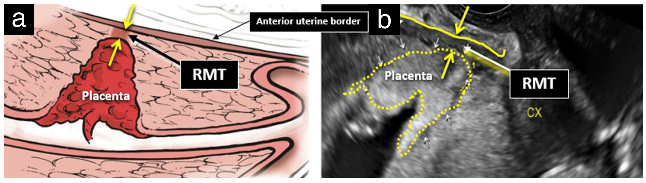

Figure 8 Schematic diagram (a) and grayscale transvaginal ultrasound image (b) of Type-2 Cesarean scar pregnancy (implanted 'in the niche'), showing thin residual myometrial thickness (RMT) between placenta and anterior uterine border. CX, cervix.

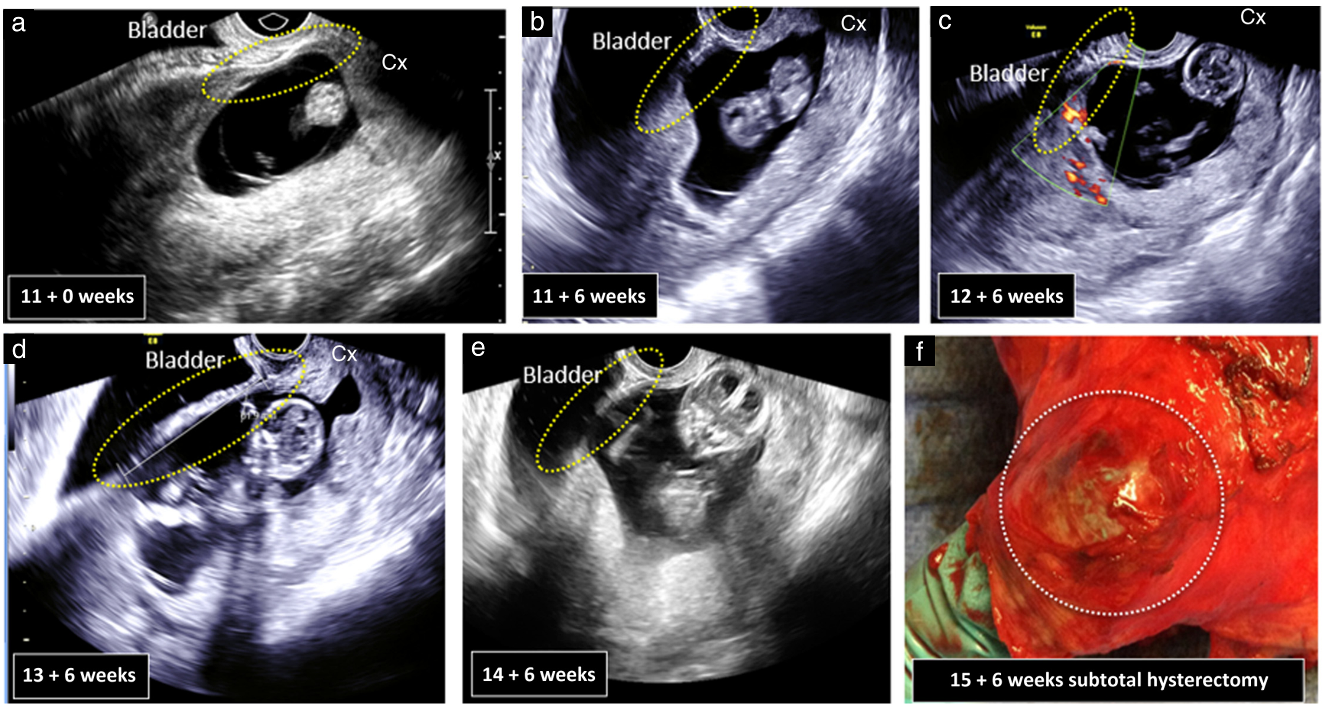

Figure 9 (a–e) Serial transvaginal ultrasound images of Cesarean scar pregnancy from 11 + 0 to 14 + 6 weeks' gestation, demonstrating anterior uterine wall with no measurable myometrium (ovals). (f) Paper-thin myometrial cover (circle) is evident on hysterectomy specimen. Cx, cervix.

outcome. In this article, we selected the publications that contained information pertinent to the clinical use of RMT measurement.

In 2012, Naji *et al.*[16] suggested classifying the niche after a CD based on its clinical value as a mild, moderate or severe scar defect. They endorsed measuring the RMT without attaching clinical consequence to parameter values or accommodating for fibrotic tissue at the site of the uterine scar.

Tower *et al.*[17] proposed a classification of niches based on RMT and the RMT/AMT ratio as the only ultrasonographic features.

The study of Kaelin Agten *et al.*[1] evaluated retrospectively the RMT in 17 patients with expectantly managed CSP. The thinnest measurements obtained at 6–8 weeks on three sagittal midline TVS images were evaluated for their prediction of outcome at delivery. Of six patients with Type-1 CSP, five were delivered by Cesarean (with normal placenta) and one underwent a Cesarean hysterectomy for placenta accreta. Of 11 patients with Type-2 CSP, 10 had a Cesarean hysterectomy for placenta increta/percreta and one underwent gravid hysterectomy for vaginal bleeding at 20 weeks. The myometrium was significantly thinner in the patients who required a hysterectomy (median, 1 (range, 0–2) mm) compared with those who did not (median, 5 (range, 4–9) mm) ($P < 0.001$). Myometrial thickness also showed a positive correlation with gestational age at delivery ($r = 0.820$; $P < 0.0005$). Cases of CSP with RMT $\geq$ 4 mm in the first trimester were associated with a good prognosis compared to those with RMT $\leq$ 2 mm. All patients in the latter group underwent Cesarean hysterectomy for PAS. The suggestion was made that patients with Type-1 CSP and RMT $\geq$ 4 mm may be good candidates for expectant management.

Jauniaux *et al.*[14] evaluated 27 women with a CSP and 27 controls with an anterior low-lying placenta or placenta previa. Of the 18 CSPs that progressed to 28 weeks, 10 had RMT < 2 mm at 6–10 weeks, of which nine were diagnosed with PAS at birth. The authors suggested that 'both the niche rupture and/or the development of accreta areas depend on the depth of the niche at the beginning of the pregnancy, the RMT and the amount of villous tissue developing inside it'. The RMT was < 2 mm in 15/27 (56%) cases of CSP and in none of the controls ($P < 0.001$). They also evaluated vascularity at the scar and found that the mean color Doppler vascularity score at 6–10 weeks was significantly higher in the CSP group compared with controls; high scores of 3 or 4 were reported in 20/27 (74%) CSP cases and only 3/27 (11%) controls ($P < 0.001$). It was concluded that the intensity of vascular changes observed, the development of PAS and the risk of hemorrhagic events and uterine rupture are related to the RMT in the first trimester of CSP.

We found three clinically oriented articles that discussed the treatment complications of CSP. They reported a higher risk of hemorrhage at treatment when the residual myometrium was thin[21,22] and a better outcome if it was thick[23].

While the RMT was not measured specifically in the systematic review of Calì *et al.*[3], they reviewed 17 studies with a total of 69 cases of expectantly managed CSP and evaluated complications, including uterine rupture. In women with a CSP and embryonic/fetal heart activity at diagnosis, uterine rupture during the first or second trimester of pregnancy occurred in 9.9% of cases, uncomplicated miscarriage occurred in 13.0% and hysterectomy was required in 15.2%. In women with a CSP but no embryonic/fetal heart activity, uterine rupture during the first trimester of pregnancy occurred in 13.4% of cases, uncomplicated miscarriage occurred in 69.1% and there was no need for hysterectomy. The authors claimed that an absent or thin myometrial layer between the gestational sac and bladder wall was typical in the scenario of uterine rupture.

Twickler *et al.*[24] measured myometrial thickness in 215 women with a placenta in proximity to the scar from a previous hysterotomy; 20 women had placenta previa and underwent CD, of whom 15 had Cesarean hysterectomy. Despite the fact that RMT was measured in the late second and third trimesters, the authors stated that a measurement of < 1 mm for the smallest myometrial thickness was predictive of myometrial invasion (sensitivity, 100%; specificity, 72%; positive predictive value, 72%; negative predictive value, 100%). The same group evaluated the occurrence of placental invasion in patients with placenta previa or low-lying placenta and prior CD[25]. Of 39 patients included, 14 (36%) had confirmed placental invasion. The only first-trimester sonographic finding associated with invasion was the smallest anterior myometrial thickness measured in the sagittal plane ($P < 0.02$), which improved the prediction of placental adherence at delivery.

3D-TVS evaluation of the RMT was also used by Shi and Du[26]. The RMT was measured successfully at the maximum depth of the anechoic dark area on the longitudinal section of the uterus. No other clinically useful data were provided.

The retrospective study of Fu *et al.*[27] evaluated the performance of the RMT measured between the bladder and the gestational sac in early pregnancy in predicting clinical outcome in 21 patients who received expectant management for CSP. Patients were classified into two groups: those who experienced serious complications during pregnancy, such as intraoperative blood loss $\geq$ 1000 mL or placenta increta or percreta ($n = 11$), and those without serious complications during pregnancy ($n = 10$). There was a statistically significant difference in RMT between the groups ($P = 0.013$). The area under the receiver-operating-characteristics curve was 0.818, and the optimal cut-off value for RMT was 3.3 mm. The authors concluded that low RMT was correlated with severe complications in patients with CSP.

Magnetic resonance imaging (MRI) was used by Amstrong *et al.*[28] to measure RMT. The authors defined RMT as 'an indentation at the site of the Cesarean scar with a depth of at least 2 mm, diagnosed by ultrasound or MRI'. We are skeptical about the value of MRI in measuring the usually thin myometrium, since the resolution of MRI may be too low to provide sufficiently accurate measurements for such a crucial component of the clinical decision-making process. We feel that high-resolution TVS is the most appropriate modality to use in obstetric and radiological services.

Noël and Thilaganathan reviewed the latest evidence on diagnosis, natural history and management of CSP[29] and, despite not stipulating a specific value for the critical RMT threshold, they concluded that 'expectant management may be appropriate in certain good prognosis cases, such as absent fetal heart activity or when the myometrial layer at the implantation site is relatively thick'.

The RMT after CD is thought to be dependent on the uterine closure technique[6]. No abnormal placentation, including CSP, was found in pregnancies following a CD in which a specific endometrium-free closure technique was utilized, irrespective of the number of prior consecutive CDs[30–32]. The authors of these articles routinely performed saline contrast sonohysterography to evaluate the lower anterior uterine segment in post-CD patients planning a subsequent pregnancy. This sentiment is shared by many obstetricians and gynecologists. While there is some discussion on the occurrence of recurrent CSP[33–36], we feel that such a practice, at this time, is unsupported by the literature.

The body of published literature attests to the potential role of RMT as an objective, straightforward and reproducible tool to stratify the prognosis of women with CSP. However, several questions remain unanswered in the literature. The published studies on RMT include cases assessed at different gestational ages and it is yet to be ascertained whether the diagnostic accuracy of this parameter performs well throughout the entire course of pregnancy. Second, most, if not all, of these studies are small series in which assessment of RMT was performed in a retrospective and unblinded manner. Third, there are few objective data on the clinical reproducibility of this sign, as none of the cited studies reported intra- and interobserver variability when measuring this parameter. Last, there is no large prospective study to date reporting on the actual strength of association between RMT and adverse outcome in CSP, or on its diagnostic performance. This is crucial, as association does not automatically imply predictive capability. It is the authors' collective opinion that RMT should be assessed in the early first trimester at the time of diagnosis of CSP for several reasons: easy assessment, timely treatment and reduced risk of post-treatment complications. Despite this, we are aware that further studies are needed to confirm its actual usefulness in the management of women with CSP. The imminent publication of the analysis of data from the International CSP Registry may provide insight on the impact of clinical management based on RMT[37].

Conclusions

In this Opinion, we discussed the diagnostic criteria of CSP and its non-sonographic and sonographic markers. Once the diagnosis is established, counseling and prognostication of such pregnancies should be based mostly on the type of implantation. Since the type of implantation has been defined in relation to the sac location using various vague and descriptive terms, including on the scar, in the niche, below or above the uterine midpoint axis, and in front or behind the endometrial line, our opinion is that a more precise and tangible tool is needed for use in day-to-day clinical practice. This tool, the RMT, while not perfect for prognosticating outcome, represents a promising metric with relevance to patient counseling. It is applicable not only to the first-trimester CSP but can also be used as a predictor of second- and third-trimester PAS. We hope that our step-by-step protocol of RMT measurement described herein becomes a useful, even gold-standard, method applicable in clinical practice. According to the pertinent literature, a value of 2 mm for the RMT seems to be the clinically relevant cut-off for classifying a CSP as low or high risk. If continued past the first trimester, a CSP with RMT $\leq$ 2 mm is associated with a high risk for complications, such as premature delivery, hemorrhagic events, PAS and hysterectomy. Measurements of $>$ 2 mm, but certainly of $\geq$ 4 mm, are associated with better outcomes.

It is also clear to us that other markers, such as peritrophoblastic vascularity, especially its cervical involvement, should not be dismissed and offer additional associations with outcome. The validity of 3D-TVS in measuring RMT should be studied further before its widespread use. TVS should be used clinically to measure RMT, as this imaging modality has been proven to be reliable and easy to use provided a generally accepted, uniform protocol is followed. We anticipate the publication of data from the International CSP Registry, which should shed light on the impact of managing CSPs based on RMT.

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