BAOJ Gynaecology
An Open Access Journal

BIO ACCENT

BAOJ Gynaecol
Review Article
Volume 3

Adoption of improved diagnostic ultrasound criteria for caesarean scar pregnancy ensuing from missed diagnoses in UK and crucial corollaries for causation/prevention of caesarean scar defects

Shashikant L Sholapurkar[1]*; Tracey Blacker[2]

[1]Consultant Obstetrician and Gynaecologist, Department of Obstetrics and Gynaecology, Royal United Hospital NHS Foundation trust, Bath, United Kingdom.

[2]Chief Ultrasonographer, Department of Obstetrics and Gynaecology, Royal United Hospital NHS Foundation Trust, Bath, United Kingdom.

***Corresponding Author: Shashikant L Sholapurkar, MD, DNB, MRCOG**

Department of Obstetrics & Gynaecology, Royal United Hospital, Bath, BA1 3NG, UK.

Tel: 44-1225-821841; Email: s.sholapurkar@nhs.net

Abstract

Caesarean scar ectopic pregnancy (CSP) is a serious condition with a continuum from complicated miscarriage to placenta praevia accreta. The reported incidence of CSP has increased exponentially. National professional organisations have published ultrasound guidelines for diagnosis of CSP which are still evolving with incremental understanding of CSP. This article describes adoption of improved comprehensive diagnostic criteria following missed diagnoses of CSPs with serious clinical consequences. In early pregnancy, if the trophoblastic mass is at or just above the internal cervical os on a transvaginal ultrasound scan with a history of previous caesarean, a deliberate effort should be made to rule out CSP. This would necessitate careful delineation of entire uterine cavity which may warrant a supplementary transabdominal scan. Importantly, contrary to the current guidelines, the trophoblastic tissue or gestational sac may appear centrally in the expanded isthmic region and not always asymmetrically in the anterior myometrium. The caesarean scar defect itself is not always visualised being sometimes completely stretched or obscured by the implanted trophoblastic mass. Embryos which would have otherwise passed out of the uterus may become entrapped in the CS scar defect, some presenting as silent nonviable pregnancies at the routine first trimester dating/screening ultrasound scans. This may explain the reported increased risk of clinical miscarriages following caesareans.

This review article, drawing inferences from the case reports presented, discusses the implications of the increasing acceptance of the hypothesis of substantial unfolding (expansion/widening) of CS defect as a mechanism for CSP and placenta praevia accreta (rather than excessive invasiveness of trophoblast). Strategies for prevention of CS defect are critically analysed. Modification of the surgical technique to minimise the ischemia of myometrial edges (avoiding undue wide/tight suturing of uterine incision) as highlighted in the "Ischemia and mal-apposition theory for CS defect" seems most crucial. This is supported by common clinical observations and the important "precautionary principle". Moreover, this solution is applicable to all caesareans (elective/early/advanced labour).

Citation: Sholapurkar SL, Blacker T. Adoption of improved diagnostic ultrasound criteria for caesarean scar pregnancy ensuing from missed diagnoses in UK and crucial corollaries for causation/prevention of caesarean scar defects. BAOJ Gynaecology. 2022; 3(1): 1001.

Received: Dec 14, 2021
Accepted: Feb 15, 2022
Published: Feb 28, 2022
Archived: www.bioaccent.org

Keywords: caesarean scar pregnancy; caesarean scar defect; caesarean scar niche; diagnosis of caesarean scar pregnancy; caesarean scar pregnancy aetiology; placenta praevia accreta syndrome; fetal head impaction at caesarean section; caesarean section in second stage.

Introduction

Caesarean section (CS) is by far the commonest major surgical procedure the humanity is subjected to. The somewhat rare long-term complications of CS are assuming importance given the sheer numbers of caesareans whcih are still continuing to increase worldwide. Caesarean scar pregnancy (CSP) is a rare form of ectopic pregnancy wherein the gestational sac is fully or partially implanted within the scar caused by previous CS [1]. The incidence of CSP has been reported to range from 1/1800 to 1/2500 of all pregnancies [2,3]. Only 19 cases of CSP were reported in the literature up to 2001, 161 by 2007 and more than 1000 by 2017 [1], an exponential rise, despite being a fraction of the total number of (unreported) cases. This has been explained partly by the increasing number of CS combined with increasing awareness and better ultrasound diagnosis. The surgical aspects of caesarean uterine incision closure have always been variable but their role in causation of caesarean scar defect (CSD) seems to have been underestimated [4]. In China, with the high CS rate of around 54.5%, the CSP is no longer a rare form of ectopic pregnancy [5].

The Royal College of Obstetricians and Gynaecologists (RCOG, UK) has published diagnostic criteria for CSP [6] similar to most other national professional organisations (Table 1). The RCOG acknowledges that up to 13% of CSPs may be misdiagnosed as intrauterine or cervical pregnancies [6]. The authors' hospital is a large teaching National Health Service (NHS) hospital in the UK and has been running a specialist Early Pregnancy Assessment Clinic (EPAC) for last 25 years conducted by qualified sonographers and senior specialist Gynaecologists. The RCOG guidelines [6] were being followed for diagnosis of CSP which emphasise the visualisation of CSD on transvaginal ultrasound scan (TVS) in early pregnancy and location of pregnancy on or in the CSD with empty uterine and isthmic cavity (Table 1). Four recent anonymised case reports are presented to show that the current criteria [6] led to failure of diagnosis of CSP with unexpected major haemorrhage in two cases. Moreover, the correct diagnosis in these cases probably mayhave been missed in most NHS hospitals in UK. We have now revised and adopted improved criteria for diagnosis of CSP in the sonography services which would have applicability nationally and internationally.

The important second part of the article discusses several available hypotheses for the aetiopathology and mechanism of CSP. The corollaries from these cases and diagnostic criteria seem consistent with the theory of unfolding (expansion) of CS defect by the implanted pregnancy leading to a spectrum from CSP to placenta praevia accreta, first proposed in 2013 [7]. This is gaining acceptance as the leading mechanism [8] and its relevance to uterine incision closure techniques will be analysed.

Table 1: The current RCOG Diagnostic Criteria for Caesarean Scar Pregnancy (CSP) on transvaginal ultrasound scan [1,6] (these could miss many CSPs).

1.	Empty uterine cavity
2.	GS or solid mass of trophoblast located anteriorly at the level of the internal os embedded at the site of the previous lower uterine segment CS scar.
3.	Thin or absent layer of myometrium between the GS and the bladder.
4.	Evidence of prominent trophoblastic/placental circulation on Doppler examination.
5.	Empty endocervical canal

GS: Gestational sac; CS: Caesarean section; CSP: Caesarean scar pregnancy.

Case 1

Unexpected massive 4 L haemorrhage during uterine suction evacuation for a "miscarriage" (missed diagnosis of CSP) requiring uterine artery embolisation.

A 28 year old gravida 2 para 1 had a routine dating and screening ultrasound scan at 11 weeks in the summer of 2021. She had no bleeding or pain. A trans-abdominal ultrasound scan (TAS) showed Trophoblastic tissue with multiple cystic areas in the isthmic area, but since it wasn't asymmetrically placed, a diagnosis of CSP was not considered (Figure 1A). A TVS (Figures 1B,1C) reported an anteverted uterus containing an irregular shaped gestational sac (GS) measuring 33 X 17 X 10 mm with an amnion but no definite yolk sac or fetal pole. The surrounding myometrium contained multiple echo-poor fluid pockets, the largest measuring 33 X 17 X 15 mm. Strong vascularity was demonstrated with power colour Doppler. Possibility of a partial mole or arterio-venous malformation (AVM) was considered due to these atypical appearances. The TVS was also repeated by a senior specialist gynaecologist. The patient was booked for an elective suction evacuation of uterus under general anaesthesia (GA) with a diagnosis of intrauterine non-viable pregnancy. Suction evacuation with a 10 mm cannula aspirated some liquor and villous/placental tissue but profuse bleeding followed quickly reaching 1500 ml and continuing unabated. Major haemorrhage protocol was instituted. Oxytocin, tranexamic acid and multiple intramuscular injections of prostaglandin-F2α were administered. Resuscitation was continued with 6 units of blood transfusion, fresh frozen plasma and fibrinogen. Uterine massage and intrauterine balloon tamponade had little success. Preparations for hysterectomy were made while awaiting interventional radiologist. Total estimated blood loss was about 4 litres. A radiologist performed femoral artery catheterisation. Under fluoroscopic guidance, catheter was advanced into right and left uterine arteries. No uterine AVM was seen on angiography. Embolisation was performed with Gelfoam slurry and the uterine bleeding came under control. Further recovery was gradual but uneventful.

While the patient was in the theatre, another gynaecologist queried a possibility of a CSP. Indeed, it transpired that the patient had undergone one uneventful elective caesarean section for breech presentation four years earlier. The ultrasound scan images in the current pregnancy were reviewed and it was noted that all the pregnancy (chorionic) tissue was right above the internal cervical os (Figures 1A,1B,1C). It was argued that the wedge-shaped scar defect could have been stretched and expanded by the developing chorionic tissue and hence would

not have been visualised even on repeated TVS examinations. The expanded isthmic area with CSP was mistaken as the entire uterus on TVS (Figure 1B).

A transabdominal and transvaginal ultrasound scan was performed six weeks later which showed a conspicuous caesarean scar defect. A pelvic MRI with contrast was performed 8 weeks after evacuation. It did not show any AVM or its remnant. This MRI confirmed a haematoma of 12 mm width in the previous caesarean scar defect the adjacent isthmic canal consistent with resolving CSP. The upper uterine cavity appeared unremarkable.

Case 2

Unexpected 2.5 L haemorrhage during uterine suction evacuation for a "miscarriage" (missed diagnosis of CSP).

A 30 year old gravida 4 para 3 (2 caesareans) had a routine dating and screening ultrasound examination at 11 weeks in the spring of 2021. She had no pain or bleeding. The TVS report read, "The uterus contains 75 X 27 X 41 mm irregular shaped GS. There is no fetal pole or yolk sac. Appearances are consistent with non-viable early pregnancy." Low level blood flow was seen on colour Doppler (Figure 2A,2B). CSP was not considered because the CS defect itself was not seen and the trophoblast was not situated asymmetrically anterior. With the lack of suspicion, a transabdominal ultrasound scan was not undertaken. Elective suction evacuation of uterus was performed under GA. Unexpectedly excessive blood loss ensued for which 5 units of oxytocin, 500 mcg Ergometrine and 1 g Tranexamic acid were given intravenously. The blood loss continued despite confirmation of empty uterus on TVS in the theatre. A Cook® balloon catheter was inserted in the uterine cavity and inflated with 60 ml of water which brought the blood loss (total of 2.5 L) under control. The balloon catheter was removed after 24 hours and further recovery was uneventful.

A couple of days later a Gynaecologist retrospectively looked at the TVS images and strongly suggested diagnosis of CSP. Other gynaecologists and sonographers were not convinced. A TVS was performed two weeks after the evacuation which reported, "Normal size uterus, normal endometrium and no retained products. At the site of caesarean scar in the anterior myometrium there is a 28 X 23 X 30 mm area with heterogeneous echogenecity." This would be consistent with resolving CSP. A further TVS performed 6 weeks later confirmed a very conspicuous CS defect measuring 11 mm wide and 8 mm deep (not visualised before evacuation).

Case 3

Repeated failure to diagnose CSP due to adherence to the current diagnostic criteria.

A 35 year old lady (3 previous caesareans) had a TVS at 9 weeks of pregnancy in a private clinic which reported an empty intrauterine GS. She had no pain or bleeding. She attended EPAC and a repeat TVS reported, "Technically difficult scan because of uterine orientation. Anteverted uterus with fundus containing a GS with a possible fetal pole of 4.7 mm with no fetal heart pulsations." The patient had a repeat TVS after 1 week which reported similar finding but the fetal pole had disappeared (Figures 3A,3B,3C). She was electively admitted for suction evacuation under GA with a diagnosis of intrauterine nonviable pregnancy (miscarriage). The Gynaecologist on the day suspected something amiss and performed a TVS. He found

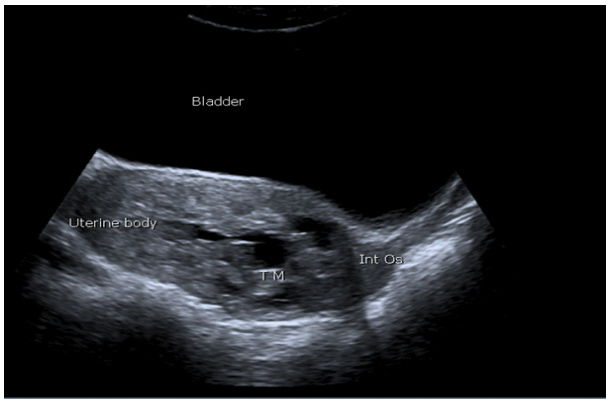

Figure 1A: Routine 11 week Transabdominal ultrasound in Case No. 1, showing a trophoblastic mass in the isthmic region of the uterus. It does not appear to be asymmetrically placed anteriorly. The CSD itself is not visible. The upper uterine body is empty. The diagnosis of CSP was not considered and hence missed.

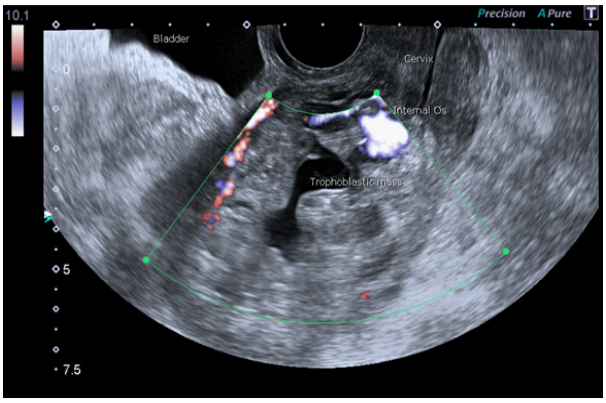

Figure 1B: TVS in Case No. 1 showing hypervascular trophoblastic mass with gestational sac quite centrally situated in the isthmus just above the internal os. CS defect itself is not seen.

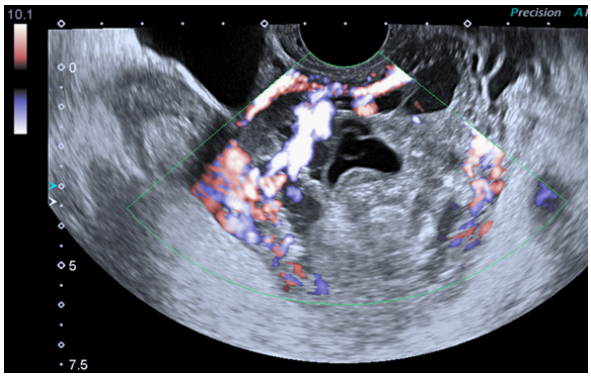

Figure 1C: TVS in Case No. 1 showing marked hypervascularity of the trophoblastic mass on colour Doppler study. The empty uterus above was missed.

the entire pregnancy tissue expanding the isthmic region just above the internal cervical os. With some deliberate effort, he was able to visualise a small normal empty uterine cavity above the pregnancy tissue. Colour Doppler study did not demonstrate increased vascularity. He explained the diagnosis of CSP leading to miscarriage and possible risk of excessive bleeding to the patient and crossmatched two units of blood. He also alerted other team members. Another specialist gynaecologist and a senior sonographer repeated the TVS on that morning but insisted on the diagnosis of intrauterine pregnancy because they expected to see a caesarean scar defect itself with pregnancy in it. A suction evacuation was performed under transabdominal

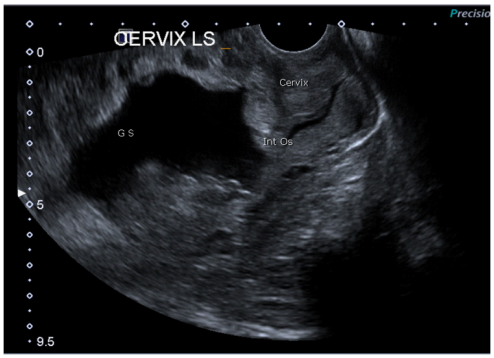

Figure 2A: TVS in Case No 2 showing an irregular GS just above the internal os somewhat centrally placed in the isthmus. CS defect itself is not visualised. The GS was mistakenly assumed to be occupying the uterine body. The actual upper uterine body, which was not easily seen on TVS, was not included in this image.

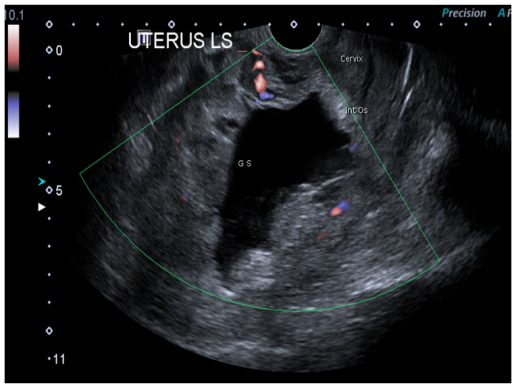

Figure 2B: TVS in Case No 2 showing mild colour Doppler flow. The shape of the GS shows lower pole to broader above the internal os differentiating it from a GS sac descending from the uterine body. The diagnosis of CSP was missed.

ultrasound guidance to be on the safer side. The procedure was uneventful without undue excessive haemorrhage. The patient declined repeat ultrasound scan after a few weeks which was offered for academic / research reasons.

Case 4

A non-viable CSP misdiagnosed as an intrauterine miscarriage during a dating scan

The sonography services had diagnosed a case of non-viable intrauterine pregnancy at the 11 weeks routine scan. There was no history of pain or bleeding. In view of the previous 3 caesareans, a gynaecologist repeated a TVS just before the scheduled suction evacuation and found a pregnancy sac of 8 weeks size expanding the isthmus and empty small uterine cavity in the body of uterus. There was no increased colour Doppler blood flow. The patient was explained the diagnosis of CSP and small risk of heavy bleeding. Blood grouping was already performed and it was not thought essential to cross-match blood as urgent supply was available. The uterine evacuation was uneventful and a TVS was repeated in theatre to confirm complete removal of pregnancy tissue.

Formulation of improved diagnostic criteria for Caesarean scar Pregnancy (CSP)

A few months later, a gynaecologist had a meeting with the most senior and lead sonographer (not previously involved in these cases) to go through the case histories and all the electronically stored ultrasound scan images. The lead sonographer

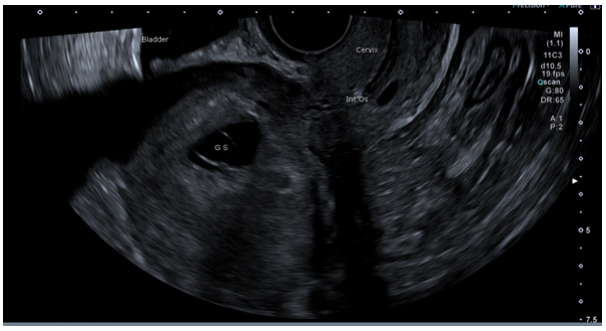

Figure 3A: TVS in Case No. 3 at 9 weeks. The gestational sac (GS) was mistakenly interpreted to be in the uterine body although it is just above the internal os with history of previous 3 CS.

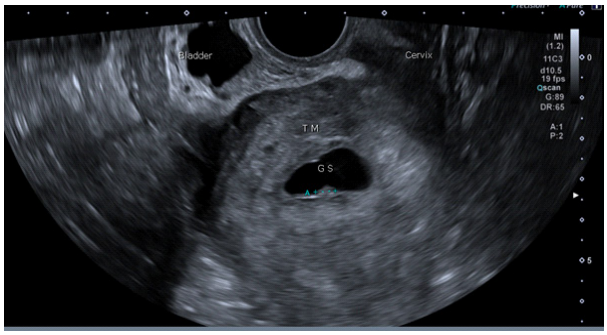

Figure 3B: TVS in Case No. 3 at 9 weeks with close up of the gestational sac above the internal os

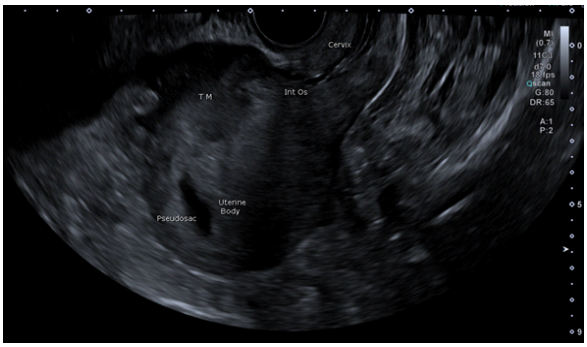

Figure 3C: TVS in Case No. 3 one week later (10 weeks). The trophoblastic mass is situated just above the internal os somewhat anteriorly in the isthmus. The GS seen in fig 3A has now disappeared but a pseudo-sac can now be seen in the uterine body. There is no continuity between cervical canal and the uterine cavity (pseudosac) because of the trophoblastic mass of the CSP in-between. The correct diagnosis of CSP would have been possible with high index of suspicion but was missed until just before the evacuation.

agreed that a diagnosis of CSP was repeatedly missed by multiple examiners. Improved guidelines with more comprehensive ultrasound diagnostic criteria for CSP were formulated and adopted for early pregnancy scans by the sonographers. These criteria are shown in Table 2. An educational session was also planned for sonographers and gynaecologists.

Diagnostic and management challenges in Caesarean Scar Pregnancy (CSP)

It can be inferred from Table 2 why the diagnosis of CSP was missed in the four cases presented above. It is possible that many of the CSPs progress to miscarriage and may or may not be associated with excessive haemorrhage. However, the cor-

rect diagnosis is important so that evacuation of these CSPs can be performed in hospitals where blood transfusion facilities and surgical/ interventional radiology expertise is available. Patients can be counselled better as well. Increased colour Doppler flow seems to increase the likelihood of major haemorrhage. The details about the management of CSP are outside the scope and not the subject of this article.

The risk of recurrence of CSP has been reported to be 3.2 -5.0% [9,10]. Recurrence seems a small random chance of repeat implantation or entrapment of embryo in the CS defect again. However, a bigger CS defect or a more severe CSP may increase the chance of repeat CSP or at least a more serious one. A few other causative factors have been postulated [1,9,10] but they are likely to be chance statistical associations/correlations. It seems prudent to deliver future normal pregnancies by elective caesarean after a previous CSP. Moreover, CSP can be repaired only in between pregnancies and generally not during a caesarean because it is not practical to excise the CSD which is extensively stretched out at term often seen as a very thin lower uterine segment (as described in the anonymised case report No. 5 below). Symptomatic CSDs seem worth repairing. Whether major CSDs should be repaired especially after serious CSPs needs further evaluation.

Case 5

Paper thin entire lower uterine segment during elective caesarean: a manifestation of expansion of CS defect and its implications

A young lady had a repeat elective CS for maternal choice. She had undergone one previous elective CS for breech performed by a senior obstetrician. During the repeat CS, the lower uterine segment was noted to be paper-thin over its entire area (15 cm wide, 10 cm high) and somewhat transparent with flakes of vernix visible underneath. However, no membranes were bulging (no dehiscence). Baby was delivered through a transverse incision and very thin myometrial edges were approximated with a single continuous layer of thin delayed absorbable suture and recovery was uneventful.

Table 2: The improved comprehensive diagnostic criteria for Caesarean Scar Pregnancy (CSP) on transvaginal and transabdominal ultrasound (adopted by our sonographers, 2021)

1.	Suspect and rule out CSP if GS or solid mass of trophoblast is located just above the internal os on TVS with history of previous CS.
2.	Empty cavity in the upper uterine body (This required careful TVS +/- TAS because the ballooned isthmic portion may be mistaken as the entire uterine body).
3.	GS or solid mass of trophoblast may be located in the CSD in the anterior myometrium Or centrally in the isthmic region with CSD not visible as expanded by the CSP.
4.	Possible thin or absent layer of myometrium between GS and the bladder. (TAS with full bladder can be useful. MRI if essential).
5.	Possible prominent trophoblastic/placental circulation on colour Doppler. Absence of increased vascularity may suggest less risk of excessive haemorrhage.
6.	Empty endocervical canal differentiates from cervical pregnancy.
7.	The "sliding test/sign" is not recommended because of unknown reliability and concern regarding patient discomfort and safety.

GS: Gestational sac; CS: Caesarean section; TVS: Transvaginal scan; TAS: Transabdominal scan; CSD: Caesarean scar defect.

It is not uncommon to see similar very thin but well developed (unfolded) lower uterine segment after one or more previous caesareans. However, it is difficult to reason how a normal myometrial thickness of lower uterine segment would become paper-thin. It seems reasonable that there would have been a CSD and the very thin myometrium of the CSD would be preferentially stretched rather than rest of the lower segment. Out of curiosity we looked back at the ultrasound images during pregnancy of the case No 5. The 11-weeks dating scan images did not include interpretable images of the isthmic area. However, we found one image at 21-weeks fetal anomaly scanning which showed a gap of a 4 cm in the anterior uterine myometrium above the cervix (Figure 4). Thus, the probable CS defect had already expanded. We have observed similar phenomenon in a few more cases. We of course do not recommend that such a defect should be intentionally sought for at mid-trimester scanning (in the absence of low-lying anterior placenta). This would generate probably unwarranted anxiety as it is not clear what to do about such an expanded CSD. It is known that a prelabour rupture of lower segment CS scar is extremely rare and dehiscences are generally silent or non-catastrophic even during labour. However, the situation is quite different with the occasional inverted T shaped incisions and ultrasound monitoring during pregnancy of any CSD in these cases should be considered. Early delivery or even closure of the defect are available options because there have been cases of catastrophic rupture of T shaped incisions in third trimester with resultant fetal morbidity/mortality.

Implications of caesarean scar defect expansion (widening/ unfolding) during pregnancy

It is important to observe and realise the phenomenon substantial widening of CS defect during pregnancy (as in case No. 5). Thus, the unfolded CS defect itself may not be seen in CSPs and the trophoblastic mass may appear to centrally/symmetrically expand the isthmic portion as in cases Nos. 1-4, with missed diagnoses of CSP. Indeed, the CS defects were seen very prominently (containing resolving haemorrhages) a few weeks after uterine evacuation. In the last decade it has been established that a viable CSP if managed expectantly in the 1st trimester evolves into placenta accreta making it one end of the spectrum of CSD complications [11].

Several etiological mechanisms for CSP have been proposed like abnormal (increased) invasiveness of placental villi [1,11], absence of decidua, invasion by the implanting blastocyst through a microscopic tract developed from the trauma of previous CS [9], the presence of CS scar may inhibit implantation of GS secondary to more global effects of prior CS surgery [12] etc. The latter two seem imaginative with no evidence to support. In 2013, a new hypothesis was proposed that the developing trophoblast implanted on the thin myometrium in the CS defect expands or widens the defect itself and the developing placenta continues this process thus completely or partly occupying the widened scar defect [7]. Thus, the abnormal invasion by the placenta or even deficient decidua do not seem to be the primary mechanisms. This expansion/widening of the CSD by the

implanted pregnancy is now gaining acceptance as a common mechanism for causation of severe cases of placenta praevia accreta syndrome (PAS) [8]. Thus, a term "Abnormally Invasive Placenta (AIP)" [13] seems less accurate/preferrable than PAS. This has more than theoretical significance as discussed next. The management modalities of PAS are outside the scope of this article. These could be regarded as fighting a fire while the important long-term solution is to prevent the fire in the first place, i. e. to minimise the occurrence of clinically significant CS defects (probably more than 5 mm in depth or more than 50% of adjacent myometrial thickness).

Profusion of hypotheses for aetiopathogenesis of caesarean scar defect (CSD)

From the discussion in this article, it is apparent that the CSD has emerged as the most important and serious long-term complication of CS. No wonder, there has been a plethora of hypotheses for aetiopathogenesis of CSD in the last decade [4,14]. However, getting bogged down with several (weak) hypotheses can result in loss of focus/direction and hence confusion and lack of practical progress. Many factors like higher or lower position of uterine scar, elective vs emergency CS, single vs double layer closure have been tested in studies examining the formation of CSDs on TVS a few months after CS. However, to achieve good sample sizes, the majority of cases included in these studies seem to be minor CSDs (between 2-5 mm). Many associations are chance findings not replicated or even contradicted by more studies. For example, a few studies show that a prelabour CS substantially increases risk of CSD (due to a higher position of uterine incision) [13,15-17] but other studies disagree [18-20]. There does seem a sound hypothesis that a higher level of CS scar in the lower segment would be associated with higher risk of PAS but the difference arises mainly between CS at cervical dilatation of 0-2 cm and 8-10 cm [13]. Importantly it is not possible/practicable avoid elective CS (except for non-medical reasons) or recommend CS late in labour. Moreover, for a CS-scar to be in the cervix, the obstetrician will need to make the uterine incision well below the upper reflection of bladder which seems unlikely. The safe level of uterine incision is largely dictated by the size/anatomy of the lower segment and level of the presenting part during the surgery. Furthermore, in the involuted non-pregnant uterus, the differences in the position of the CS scar in the isthmus of uterus would be very minor. Remarkably, during the second stage caesareans with low fetal head, the younger obstetricians in UK have adopted to make the transverse uterine incision a lot higher i.e., almost 10 cm or more above the reflection of the bladder. This is because of mistaken fear of making incision into cervix or upper vagina which seems based on misunderstanding of relationship of bladder to the lower uterine segment at full dilatation of cervix. Not surprisingly, the impacted fetal head has to be lifted up by a longer distance into the uterine incision. This has resulted in increasing major difficulties / complications in delivering the low fetal head in recent years in the UK. It would be safer to reflect the bladder down by about 5 cm and then make an incision about 5 cm above the 'original' reflection / attachment of bladder, still well away from the cervix or vagina. Any possible small reduction in the risk of PAS in future pregnancies would be an additional bonus. Importantly, for the reduction of CSPs and PAS, the main focus should be on the 'uterine incision closure techniques' as discussed next.

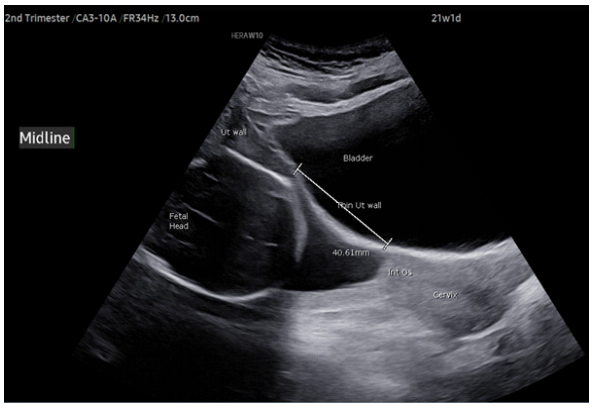

Figure 4: Retrospective review of Transabdominal ultrasound scan images of 21 weeks fetal anomaly scan in Case No. 5. One can see a gap of 4 cm (very thin myometrium) in the anterior uterine wall just above the internal os. This cannot be an artefact. It seems to represent a previous CS defect undergoing stretching/expansion during this pregnancy. At the repeat CS, the entire lower segment was paper thin without frank dehiscence.

It seems a physiological approach to close a long linear incision with the traditional longitudinally placed sutures along its length. Novel approaches like a purse-string suture have been explored but would require plenty of robust data to support. It is acceptable to form hypotheses from statistical associations based on data in clinical studies, however the strength of these associations (biological plausibility) must be critically analysed. Hypotheses with weak prior odds, with statistically significant associations arising largely by chance, fail to be confirmed in the long run [21,22]. Hence, many scientists and statisticians favour Bayesian approach [21,22]. Most innovations come from detailed observations leading to hypothesis formation which then can be subjected to clinical studies rather than the other way around.

Primacy of ischemia and mal-apposition theory for caesarean scar defect (CSD)

The observation that significant thickness of myometrium is missing at the site of CSD tends to suggest that much of the myometrium is likely to have undergone (ischemic) necrosis during the healing of CS scar. There seems hardly any other good explanation for the missing myometrium. The approximation of myometrial edges is generally adequate or even overenthusiastic. Hence, the "Ischemia and Mal-Apposition Hypothesis for CS Niche" lays more emphasis on the devascularisation of sutured myometrium [4]. This can occur due to excessively tight suturing or even overenthusiastic buckling together of myometrium taking very wide bites during the closure of uterine incision [4]. Any ischemic necrosis would occur in just a few hours after the suturing but a defect will be apparent after several weeks. Most importantly, minimising the ischemia of the sutured myometrium is an eminently 'correctable' factor compared to other uncontrollable factors like avoiding prelabour CS or before 8 cm cervical dilatation. Following principles are suggested to minimise ischemia and CSD.

1. Avoid locking or very tight non-locking constricting suture-bites for both layers of closure of myometrial edges.

2. Do not rush the closure of uterine incision for rapid/hasty haemostasis which often results in very tight sutures. Obtain haemostasis by applying multiple Green-Armitage clamps to incision edges and then perform deliberate meticulous closure of the incision. An excess of 100 ml blood loss from myometrial edges (even if statistically significant) is of no conse-

quence. The length of resultant sutured incision again seems of no relevance and a shorter length may not be an advantage, but rather constricting.

3. If myometrial edges are thick then a two-layer technique (avoiding too much of decidua) would achieve better approximation but care should be taken to minimise any devascularisation [4,7]. One could consider a few interrupted sutures for the second layer.

4. If myometrial edges are thin (e.g. less than 5-8 mm thick), then a single layer closure would suffice. Any persistent bleeder in the edges can be controlled with local isolated sutures.

5. There seems no benefit in bringing together adjacent intact myometrial surface over the first layer. In fact, it requires forcefull pulling of sutures which would cause ischemia of the incised myometrium at the incision [4,7]. This seems a deleterious technique which has inadvertently become fashionable in the British practice [4,7]. It seems best to avoid including excessive myometrial tissue in the needle bites. Bad techniques can appear paradoxically more attractive without detailed thinking. Even when the lower uterine segment is very thin (after previous CS), doubling the myometrial edges at the incision is unlikely to serve any purpose. The rest of the lower segment remains thin and would revert back to a (probable) pre-existing CSD after the post-partum involution of uterus.

Randomised controlled trials to examine the increased risk of major CSDs with a tight devascularising suturing technique would be highly desirable but would be difficult because of the subtle surgical variations. Moreover, the same surgeons may not be able to switch between two contrasting techniques over the time of the trials. The “ischemia” hypothesis seems to have a strong enough biological basis to be taken seriously and implemented (unless proven otherwise) even on a “precautionary principle”. A prominent example of the precautionary principle has been the (somewhat delayed) rational adoption of wearing of facemasks by western countries during the Covid pandemic despite non-conclusive or even contrary evidence [23].

Conclusions

Learning from a few missed diagnoses of CSPs, we have adopted more comprehensive ultrasound diagnostic criteria for CSP. These highlight that the caesarean scar defect may not always be visualised being stretched over the trophoblastic mass which may be situated centrally or anteriorly around the level of internal os. The delineation of empty uterine cavity needs careful attention often requiring additional transabdominal ultrasound scan. The hypothesis that the placenta praevia accreta syndrome (PAS) arises from the developing placenta expanding the CSD [7] rather than abnormal invasiveness of placenta is gaining acceptance [8]. Just as it is important to prevent the fire rather than just fighting it, preventing CSDs needs higher priority. A focus on minimising ischemia of myometrial edges due to undue tight suturing of uterine incision seems crucial (applicable to prelabour as well as advanced labour CS) as highlighted in the “Ischemia and mal-apposition theory for CSD” [4] seems most crucial based on clinical observations and the “precautionary principle”.

Declarations

The authors have no conflict of interest or funding to declare. The clinical aspects discussed are based on 35 years of obstetric experience of the first author. The first and second authors contributed to correcting the missed diagnoses of CSPs and formulating the improved ultrasound diagnostic criteria.

References

1. Jayaram PM, Okunoye GO, Konje J (2017). Caesarean scar ectopic pregnancy: Diagnostic challenges and management options. The Obstetrician & Gynaecologist 19: 13–20.

2. Seow KM, Huang LW, Lin YH, Lin MY, Tsai YL et al. (2004) Caesarean scar pregnancy: issues in management. Ultrasound Obstet Gynecol 23: 247–253.

3. Jurkovic D, Hillaby K, Woelfer B, Lawrence A, Salim R et al. (2003) First trimester diagnosis and management of pregnancies implanted into the lower uterine segment Caesarean section scar. Ultrasound Obstet Gynecol 21: 220–227.

4. Sholapurkar SL (2018) Etiology of Cesarean Uterine Scar Defect (Niche): Detailed Critical Analysis of Hypotheses and Prevention Strategies and Peritoneal Closure Debate. J Clin Med Res 10: 166-173.

5. Shi XM, Wang Y, Zhang Y, Wei Y, Chen L, et al. (2018). Effect of Primary Elective Cesarean Delivery on Placenta Accreta: A Case-Control Study. Chinese medical journal 131: 672–676.

6. Elson CJ, Salim R, Potdar N, Chetty M, Ross JA, et al. on behalf of the Royal College of Obstetricians and Gynaecologists (2016) Diagnosis and management of ectopic pregnancy. BJOG 123: e15–e55.

7. Sholapurkar SL (2013) Increased incidence of placenta previa and accreta with previous caesareans–a hypothesis for causation. J Obstet Gynaecol 33: 806-809.

8. Coutinho CM, Noel L, Giorgione V, Marçal LCA, Bhide A, et al. (2021) Placenta Accreta Spectrum Disorders and Cesarean Scar Pregnancy Screening: Are we Asking the Right Questions? Rev Bras Ginecol Obstet 43: 347-350.

9. Qian ZD, Guo QY, Huang LL (2014) Identifying risk factors for recurrent caesarean scar pregnancy: a case-control study. Fertil Steril 102: 129–134.e1.

10. Ben Nagi J, Helmy S, Ofili-Yebovi D, Yazbek J, Sawyer E, et al (2007) Reproductive outcomes of women with a previous history of Caesarean scar ectopic pregnancies. Hum Reprod 22: 2012–2015.

11. Sinha P, Mishra M (2012) Caesarean scar pregnancy: a precursor of placenta percreta/accreta. J Obstet Gynaecol 32(7):621-623.

12. Naji O, Daemen A, Smith A, Abdallah Y, Bradburn E, et al. (2012) Does the presence of a caesarean section scar influence the site of placental implantation and subsequent migration in future pregnancies: a prospective case-control study. Ultrasound Obstet Gynecol 40: 557–561.

13. Kamel R, Eissa T, Sharaf M, Negm S, Thilaganathan B (2021) Position and integrity of uterine scar are determined by degree of cervical dilatation at time of Cesarean section. Ultrasound Obstet Gynecol 57: 466–470.

14. Vervoort AJ, Uittenbogaard LB, Hehenkamp WJ, Brolmann HA, Mol BW, et al. (2015) Why do niches develop in Caesarean uterine scars? Hypotheses on the aetiology of niche development. Hum Reprod 30: 2695- 2702.

15. Shi XM, Wang Y, Zhang Y, Wei Y, Chen L, et al. (2018) Effect of Primary Elective Cesarean Delivery on Placenta Accreta: A Case–Control Study. Chin Med J 131: 672–676.

16. Colmorn LB, Krebs L, Klungsoyr K, Jakobsson M, Tapper AM, et

al. (2017) Mode of ´ first delivery and severe maternal complications in the subsequent pregnancy. Acta Obstet Gynecol Scand 96: 1053–1062.

17. Kamara M, Henderson JJ, Doherty DA, Dickinson JE, Pennell CE (2013) The risk of placenta accreta following primary elective caesarean delivery: a case–control study. BJOG 120: 879–886.

18. Armstrong V, Hansen WF, Van Voorhis BJ, Syrop CH (2003) Detection of cesarean scars by transvaginal ultrasound. Obstet Gynecol 101: 61–65.

19. Vikhareva Osser O, Valentin L (2010) Risk factors for incomplete healing of the uterine incision after caesarean section. BJOG 117: 1119–1126.

20. van der Voet LLF, Bij de Vaate AM, Heymans MW, Brolmann HAM, Veersema S, et al. (2017) Prognostic Factors for Niche Development in the Uterine Caesarean Section Scar. Eur J Obstet Gynecol Reprod Biol 213: 31–32.

21. Spiegelhalter D (2019) Answering questions and claiming discoveries. In: The art of statistics: Learning from data. 1st ed. Milton Keynes (UK): Penguin Random House UK; Chapter 10, Learning from experience the Bayesian way; p. 253–339.

22. Bergstrom CT, West JD (2020) The susceptibility of Science. In: Bergstrom CT, West JD, editor. Calling Bullshit- The Art of Scepticism in a Data-Driven World, 1st edn. London, UK: Allen Lane, Penguin Random House; pp. 206–41

23. Greenhalgh T, Schmid MB, Czypionka T, Bassler D, Gruer L (2020) Face masks for the public during the covid-19 crisis. BMJ. 369: m1435.