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ORIGINAL ARTICLE *Early pregnancy*

# Does the presence of a Caesarean section scar affect implantation site and early pregnancy outcome in women attending an early pregnancy assessment unit?

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**STUDY QUESTION:** Are there any differences in the location and distance to the internal cervical ostium of the implantation site of the intrauterine gestation sacs, early pregnancy symptoms and pregnancy outcome at 12 weeks gestation between women with and without a previous Caesarean section (CS)?

**SUMMARY ANSWER:** The presence of a CS scar affects the site of implantation, and the distance between implantation site and the scar is related to the risk of spontaneous abortion.

**WHAT IS KNOWN ALREADY?:** Little is known about the impact of a CS scar on implantation other than the risk of Caesarean scar pregnancy (CSP). Furthermore, there is a paucity of information on how the proximity of implantation to the scar impacts on pregnancy outcome in the first trimester.

**STUDY DESIGN, SIZE, AND DURATION:** A prospective cohort study conducted over 15 months in the early pregnancy unit of a London Teaching Hospital. Three hundred and eighty women underwent a transvaginal scan at 6–11 weeks of gestation. A total of 170 women had undergone ≥1 CS, and 210 women had no history of CS.

**PARTICIPANTS/MATERIALS, SETTING, METHODS:** The 380 women were recruited as consecutive non-selected cases. The relationship between the implanted sac and the CS scar was assessed by quantifiable measures and by subjective impression. Logistic regression analysis was used to determine the influence of the presence of a CS scar on pregnancy outcome. The final outcome of the study was the viability of the pregnancy at 12 weeks.

**MAIN RESULTS AND THE ROLE OF CHANCE:** Implantation was most frequently posterior (53%) in the CS group and fundal in the non-CS group (42%). Gestation sac implantation was 8.7 mm lower in the CS group (95% confidence interval (CI) 6.7–10.7, $P < 0.0001$). Presenting complaints differed in women with and without a previous CS ($P = 0.0009$). More frequent vaginal bleeding [73 versus 55%, difference −18, 95% CI (−27 to −8%] yet no clearly increased spontaneous abortion rates were noted in the CS group compared with the non-CS group (adjusted odds ratio = 1.1, 95% CI 0.6–1.9, $P = 0.74$). Subjective impression showed that in eight cases the implantation site crossed the scar, seven of which resulted in spontaneous abortion, while the remaining case survived to term complicated by placenta praevia and post-partum haemorrhage. The subjective impression of the examiner was supported by the measurements of distance between implantation site and CS scar.

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**LIMITATIONS, REASONS FOR CAUTION:** A weakness of the study is the lack of a reference technique to verify the location of implantation.

**WIDER IMPLICATIONS OF THE FINDINGS:** This study adds further support to the hypothesis that the presence of a CS on the uterus impacts on the implantation site of a future pregnancy. The possibility that the CS scar has an impact on the risk of spontaneous abortion should be further studied. Caution must be exercised when implantation occurs near to, and crosses, a CS scar as this is not always associated with the diagnosis of CSP. A potential limitation of the study is that we did not examine scar dimensions and morphology.

**STUDY FUNDING/COMPETING INTEREST(S):** The authors have no competing interests to declare. The study was not supported by an external grant.

**Key words:** Caesarean section scar / implantation / placenta / Caesarean scar pregnancy / transvaginal sonography

# Introduction

The number of Caesarean sections (CSs) being carried out has increased, and accordingly the long-term impact of this operation on reproductive outcomes is a concern (Hemminki, 1986). To date, there has been little discussion regarding the influence of CS scars on early pregnancy events, such as implantation and spontaneous abortion. Most studies have included very small numbers of patients with no definite conclusions (Hemminki, 1996). Hemminki (1996) reviewed the impact of CS on future reproduction and concluded that CS is a risk factor for lowered fertility and early pregnancy loss, including ectopic pregnancy and spontaneous abortion. However, the clinical relevance of the relationship between implantation and CS scars visualized using transvaginal sonography (TVS) was not specifically explored in this review or in any study to date.

Spontaneous abortion is the most common complication of pregnancy (Salker *et al*., 2010), with chromosomal abnormalities associated with increasing maternal age being responsible for >50% (Macklon *et al*., 2002). At present, the maternal response to an implanting embryo is believed to be the most important factor in determining pregnancy outcome. This maternal response is termed decidualization, a process that occurs in all species where implantation causes breaching of the luminal endometrial epithelium (Brosens and Gellersen, 2010). There is a growing body of evidence to suggest that early pregnancy loss is caused by impaired decidualization (Salker *et al*., 2010), and it is possible that the presence of a CS scar in the uterus may further compromise this process. Another mechanism may be impairment of junctional zone contractility secondary to oxidative stress at the site of scarred endometrium (Naji *et al*., 2012a,b).

A deleterious effect of the presence of a CS scar on the uterus was further supported by Ben-Nagi who suggested there might be a link between altered uterine immunobiology, CS and embryo implantation (Ben-Nagi *et al*., 2009). They studied the effect of CS on the endometrium in premenopausal women with a history of CS; endometrial samples were taken from both the CS scar site and posterior uterine wall and the results were compared with samples obtained from the posterior uterine wall in women who had spontaneous vaginal deliveries only. The most significant difference was that fewer leukocytes and less vascularization were found at the scar site than in the endometrium of the unscarred uterus. In addition, they found a delay in endometrial maturation at the scar area, and this delay might have been a result of disruption in steroid receptor expression.

A further important consequence of CS is Caesarean scar pregnancy (CSP). Ash *et al*. (2007) reported a rise in published articles on CSP; however, the true prevalence of CSP is not known. They question whether this apparent increase in number is related to the increase in CS deliveries or better recognition of CSP with TVS. Distinguishing between CSP, cervical pregnancy and an intrauterine gestation sac implanted low in the cavity may be difficult (Timor-Tritsch *et al*., 2012). A recent review reported that the diagnosis was missed in 107 out of the 751 cases reviewed (Timor-Tritsch *et al*., 2012). Just as concerning is the possibility of a false-positive diagnosis of CSP, leading to the termination of a viable, correctly located pregnancy.

We aimed to study the impact of the presence of a CS scar on the location of the implantation site, symptoms and risk of spontaneous abortion for women attending an early pregnancy unit (EPU) for assessment.

# Patients and Methods

This prospective cohort study was undertaken in the EPU of a London university teaching hospital. The local ethics committee approved the protocol and patients gave written informed consent prior to participation. During the 15-month study period (June 2010 to September 2011), consecutive non-selected cases were recruited. Any pregnant woman attending for an early pregnancy scan was given an information sheet describing the nature and the aim of the study and a health questionnaire concerning her past obstetric history. Generally, there are three criteria for assessing women in our EPU: vaginal bleeding and/or pain, for patient anxiety or for reassurance in the event of previous ectopic pregnancy or spontaneous abortion. From this cohort, we recruited patients who fulfilled the following eligibility criteria:

(i) singleton intrauterine pregnancy,
(ii) gestational age 6–11 weeks,
(iii) no previous history of open uterine surgery or classical CS, except lower uterine segment CS.

Patients with cervical or interstitial ectopic pregnancies of unknown location (Barnhart *et al*., 2011), and with complete or incomplete spontaneous abortion were excluded from the study (Wang *et al*., 2010).

Patients completing the health questionnaire were requested to note their previous obstetric history, the number of previous CS and other demographic data, i.e. age, ethnicity and BMI as well as current pregnancy symptoms. Vaginal bleeding was recorded using a modified pictoral blood loss assessment chart (PBAC) (Higham *et al*., 1990), ranging from 1 in cases of brown discharge to five in cases of bleeding with clots and flooding (Fig. 1).

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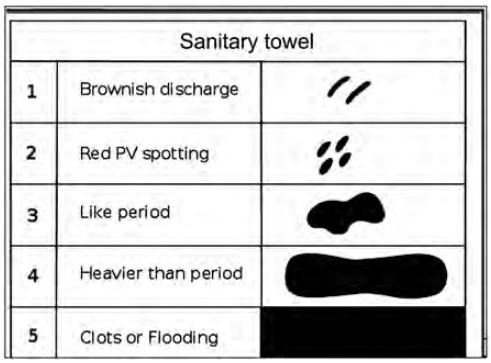


**Figure 1** A modified pictoral blood loss assessment chart (Higham *et al.*, 1990).

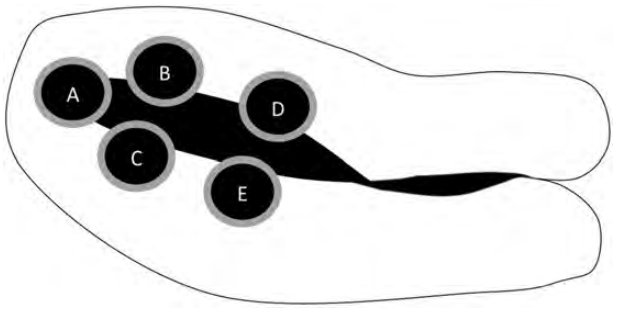


**Figure 2** Gestational sac implantation sites in relation to the endometrial cavity (A: fundal, B: anterior, C: posterior, D: low-lying anterior, E: low-lying posterior).

All examinations were performed using a Voluson® E8 Expert (GE Healthcare, Wisconsin, USA) ultrasound system equipped with a 5–9 MHz vaginal probe. When an intrauterine pregnancy was identified, the following ultrasound findings were documented:

(i) Implantation site in relation to the endometrial cavity. For the purposes of this study and to obtain consistent findings, it was decided to have only five subgroups of gestational site implantation in relation to the endometrial cavity (Fig. 2):
   (a) anterior,
   (b) posterior,
   (c) Fundal,
   (d) low-lying anterior,
   (e) low-lying posterior.

   We adopted the definition of implantation site from our previous publication (Abdallah *et al.*, 2012). The implantation site is visualized in the sagittal plane as a hyperechoic ring that occupies one side of the implanted gestational sac and protrudes into the endometrial lumen (Fig. 3). It represents the maternal decidual reaction and the beginning of maternal–fetal circulation. This area is also believed to be responsible for future placental formation and development (Brosens and Gellersen, 2010).

(ii) Distance between the implantation site and the internal cervical ostium (os). This was taken from the lower end of the hyperechoic trophoblast ring of the gestational sac to the internal cervical os in the sagittal plane, as illustrated in Fig. 3. Methods of identifying the internal cervical os were adopted from our previous publication (Naji *et al.*, 2012a,b).

(iii) Subjective assessment of the relationship between the implantation site and CS scar. Four classifications were used (Fig. 4):
   (a) away from the scar,
   (b) close to the scar,
   (c) crossing the scar,
   (d) inside the scar, known as CSP.

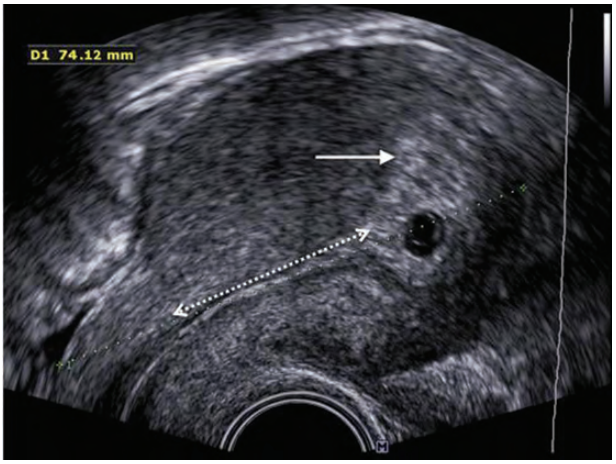


**Figure 3** Implantation site in non-scarred uterus posterior to the endometrial cavity (solid arrow) and implantation site-internal cervical ostium (os) (dotted arrow).

Methods of diagnosing CSP were adopted from Ash *et al.* (2007). In order to discriminate between implantation close to or crossing the scar and a spontaneous abortion passing through the lower part of the uterus, we ensured there was an embryonic heartbeat when appropriate, a negative sliding sign as well as the presence of trophoblast vascularity.

The main outcome of the study was the viability of the pregnancy at 12 weeks of gestation. All data were entered regularly into a designated research database and checked for missing, out of range and inconsistent values.

## Statistical analysis

Baseline characteristics between women with and without previous Caesarean in demographic variables are presented using descriptive statistics. Differences between the patients with and without Caesarean history are investigated using statistical significance testing for the following variables: presenting symptoms ($\chi^2$ test), implantation sites ($\chi^2$ test), distance from the implantation site to the internal cervical os (*t*-test), PBAC scores (logistic regression) and pregnancy outcome (multiple logistic regression). However, we always report effect sizes with 95% confidence intervals (CI) as the most important result. For the association of PBAC scores with Caesarean history, the c-statistic was used as a measure of effect size. This estimates the probability that a woman with a previous Caesarean has a higher score than a woman without a previous CS. The multiple logistic regression analysis to study the influence of CS on pregnancy outcome includes the following covariates to correct for confounding: implantation site, age, parity and presenting complaint. In addition we explore whether the effect of Caesarean history is modified by the covariates through interaction terms. There were no missing values and no observations were lost to follow-up.

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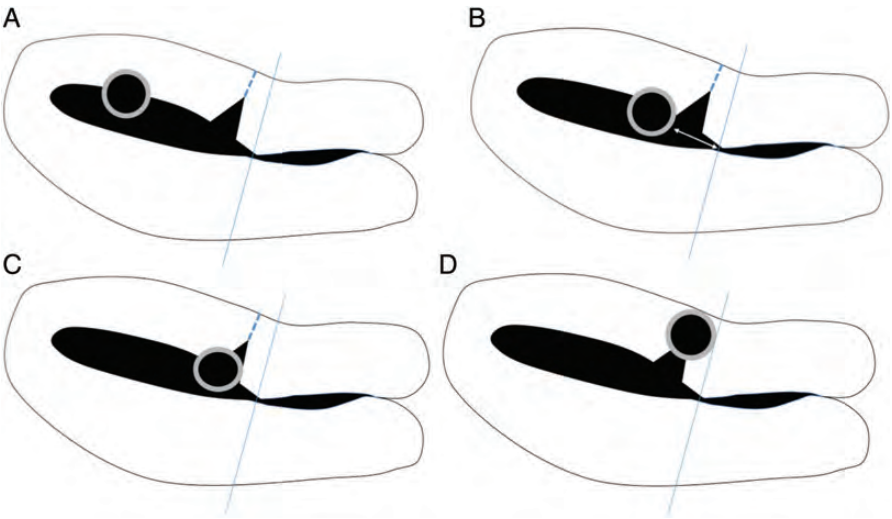


**Figure 4** Classification of gestational sac implantation in relation to the Caesarean scar by subjective impression (A: away from scar, B: close to scar, C: crossing the scar, D: inside the scar causing CSP).

# Results

The study population comprised 380 women, of which 170 cases had at least one previous Caesarean delivery and 210 cases had no previous uterine surgery. Overall, 306/380 cases (81%) were symptomatic (bleeding and/or pain) and 74/380 (19%) had no symptoms. Women with a previous Caesarean delivery tended to be slightly older (median 34 versus 33 years old) to have a slightly higher gravidity (median four versus three) and a higher BMI (median 27 versus 25 kg/m$^2$) than women without previous Caesarean delivery. Moreover, there are more whites and smokers among women with a history of Caesarean delivery (64 versus 56% and 14 versus 7%, respectively). The parity and number of spontaneous abortions was comparable across the two groups (Table I).

There was a significant association between the presenting criteria and the presence of a Caesarean scar (Table II, $P = 0.0009$). In the non-CS group 55% cases presented with vaginal bleeding compared with 73% in the CS group (difference −18%, 95% CI −27 to −8%). Women without a previous CS presented more often with lower abdominal cramps or for a reassurance scan than women who had a previous CS (difference 11%, 95% CI 3–18% and difference 8%, 95% CI −0 to +15%, respectively).

For vaginal bleeding the median PBAC score was 2/5 in the CS and 3/5 in the non-CS group. Women who have had a previous CS tend to have higher PBAC scores than women without a previous CS (c-statistic = 0.69, 95% CI 0.63–0.74).

The frequency of different gestational sac implantation sites between the two groups is illustrated in Table III. There is a significant difference in the site of implantation between the two groups ($P < 0.0001$). In the CS group posterior implantation was observed most frequently (difference −23%, 95% CI −32 to −13%), while in the non-CS group fundal implantation was observed most frequently (difference 19%, 95% CI 10–28%). Low-lying anterior and posterior implantations occurred in low but similar frequencies in non-CS and

**Table I Demographic characteristics of patients with and without prior history of Caesarean delivery.**

| Variable | Statistic | Caesarean in the past | |
|---|---|---|---|
| | | No ($n$ = 210) | Yes ($n$ = 170) |
| Age (years) | Median (min, Q1, Q3, max) | 33 (18, 28, 37, 45) | 34 (22, 29, 39, 46) |
| Gravity | Median (min, Q1, Q3, max) | 3 (2, 2, 4, 7) | 4 (2, 3, 4, 8) |
| Parity | Median (min, Q1, Q3, max) | 2 (0, 1, 3, 5) | 2 (1, 1, 3, 5) |
| Previous spontaneous abortion | Median (min, Q1, Q3, max) | 0 (0, 0, 1, 5) | 0 (0, 0, 1, 3) |
| BMI (kg/m$^2$) | Median (min, Q1, Q3, max) | 25 (18, 23, 28, 37) | 27 (20, 24, 30, 40) |
| Smoking = non-smoker | $N$ (%) | 164 (78%) | 118 (69%) |
| Smoking = ex-smoker | $N$ (%) | 32 (15%) | 28 (16%) |
| Smoking = current smoker | $N$ (%) | 14 (7%) | 24 (14%) |
| Ethnicity = white | $N$ (%) | 117 (56%) | 109 (64%) |
| Ethnicity = black | $N$ (%) | 46 (22%) | 33 (19%) |
| Ethnicity = Asian | $N$ (%) | 35 (17%) | 20 (12%) |
| Ethnicity = Other | $N$ (%) | 12 (6%) | 8 (5%) |

Min, minimum; Q1, first quartile; Q3, third quartile; max, maximum. Significance between groups was not assessed.

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**Table II Differences in the frequency of presenting criteria in the early pregnancy unit in patients with and without prior history of Caesarean delivery ($P = 0.0009$).**

| Presenting criteria | Caesarean in the past | | | Number of Caesareans | | Total |
|---|---|---|---|---|---|---|
| | No, *n* (%) | Yes, *n* (%) | Column percentage difference (95% CI) | 1, *n* (%) | >1, *n* (%) | *n* |
| Bleeding | 115 (55) | 124 (73) | −18 (−27, −8) | 98 (78) | 26 (59) | 239 |
| Pain | 47 (22) | 20 (12) | 11 (3, 18) | 10 (8) | 10 (23) | 67 |
| Reassurance | 48 (23) | 26 (15) | 8 (−0, 15) | 18 (14) | 8 (18) | 74 |
| Total | 210 | 170 | | 126 | 44 | 380 |

CI, confidence interval.

**Table III Differences in the distribution of different implantation sites within the uterine cavity between the Caesarean and non-Caesarean groups of women ($P < 0.0001$).**

| Implantation site | Caesarean in the past | | | Number of Caesareans | | Total |
|---|---|---|---|---|---|---|
| | No, *n* (%) | Yes, *n* (%) | Column percentage difference (95% CI) | 1, *n* (%) | >1, *n* (%) | *n* |
| Anterior | 47 (22) | 33 (19) | 3 (−5, 11) | 22 (17) | 11 (25) | 80 |
| Fundal | 89 (42) | 39 (23) | 19 (10, 28) | 31 (25) | 8 (18) | 128 |
| Low-lying anterior | 4 (1.9) | 4 (2.4) | −0.5 (−4.2, 2.8) | 3 (2.3) | 1 (2.2) | 8 |
| Low-lying posterior | 5 (2.4) | 2 (1.2) | 1.2 (−2.1, 4.4) | 1 (0.8) | 1 (2.2) | 7 |
| Posterior | 65 (31) | 91 (54) | −23 (−32, −13) | 68 (54) | 23 (52) | 156 |
| Scar pregnancy | 0 | 1 (0.6) | (nd) | 1 (0.8) | 0 | 1 |
| Total | 210 | 170 | | 126 | 44 | 380 |

CS groups (difference −0.5%, 95% CI −4.2 to 2.8%, and difference 1.2%, 95% CI −2.1 to 4.4%, respectively).

For the distance between the implantation site and the internal cervical os, there was a significant association between the mean distance and the presence of a CS scar ($P < 0.0001$). The mean distance among women with and without previous CS was 26.6 and 35.3 mm, respectively (Fig. 5, difference 8.7 mm, 95% CI 6.7–10.7 mm).

The pregnancy outcome at 12 weeks in both groups is illustrated in Table IV. Among women with a previous CS, 29% miscarried, compared with 24% of women without a previous CS. In a multivariable analysis, taking implantation site, presenting complaint, age and parity into account, previous CS did not have an independent effect on the outcome at 12 weeks [odds ratio (OR) = 1.1, 95% CI 0.6–1.9, $P = 0.74$].

In the CS group ($n = 170$), subjective impression of the location of the implantation showed 141 cases away from the scar, 20 close to the scar, 8 cases crossed the scar and 1 case implanted into the scar (CSP). CSP was diagnosed at 7 weeks of gestation and managed by suction and evacuation under direct ultrasound guidance. The subjective impression of the examiner was supported by the measurements of implantation to CS scar distance. The mean distance for the cases implanted away from the scar was 29.6 mm, while it was 14.7 and 3.8 mm for the ones implanted close and crossing the scar, respectively. There was no overlap in the distances between these groups.

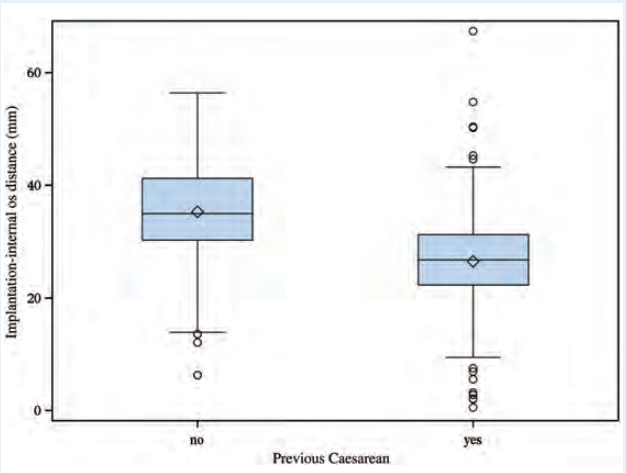


**Figure 5** Differences in the distance between the implantation site and the internal cervical os among the Caesarean and non-Caesarean groups ($P < 0.0001$). Diamonds represent group means, boxes represent the interquartile ranges (IQR), horizontal bars within the boxes represent the medians, whiskers represent the lowest/highest data points within 1.5 IQR of the lower/upper quartiles and dots represent outliers.

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**Table IV Pregnancy outcome at 12 weeks of gestation among the Caesarean and non-Caesarean groups of women.**

| Outcome at 12 weeks | Caesarean in the past | | Number of Caesareans | | Total |
|---|---|---|---|---|---|
| | No, *n* (%) | Yes, *n* (%) | 1, *n* (%) | >1, *n* (%) | *n* |
| Spontaneous abortion | 51 (24) | 49 (29) | 35 (28) | 14 (32) | 100 |
| Viable | 159 (76) | 120 (71) | 90 (72) | 30 (68) | 279 |
| Total | 210 | 169 | 125 | 44 | 379[a] |

Comparisons between Caesarean and non-Caesarean groups were not assessed.
[a]One case diagnosed with Caesarean scar pregnancy (CSP) and was managed by suction evacuation and therefore excluded from the analysis.

**Table V Implantation site by subjective impression and outcome at 12 weeks.**

| | Outcome at 12 weeks | | | |
|---|---|---|---|---|
| | Viable, *n* (%) | Spontaneous abortion, *n* (%) | | Total |
| Implantation site by subjective impression | | | | |
| Away from the scar | 110 (78) | 31 (22) | | 141 |
| Close to the scar | 9 (45) | 11 (55) | | 20 |
| Crossing the scar | 1 (13) | 7 (88) | | 8 |
| Total | 120 | 49 | 1[a] | 170 |

[a]One case of CSP.

Among the cases where implantation was away from the scar, 22% had a spontaneous abortion, compared with 55 and 88% among women with implantation close to and crossing the scar, respectively. The probability of a spontaneous abortion increased as the implantation site approached the scar (Table V). Multivariate analysis taking presenting complaint, age and parity into account suggests that closeness to the scar influences the risk of spontaneous abortion ($P = 0.0003$, OR away versus crossing = 0.024, 95% CI 0.02–0.263, OR close versus crossing = 0.114, 95% CI 0.009–1.395). Among the eight cases that implanted across the scar, seven cases ended with spontaneous abortion and one case survived to term. The surviving embryo was followed up closely throughout the course of the pregnancy. At the 12-week scan a single viable intrauterine pregnancy was identified and a low-lying placenta was confirmed, which subsequently evolved into a grade II placenta praevia (Fig. 6A–C). An elective repeat CS delivery at 39 weeks of gestation was carried out for this case that was straightforward other than an estimated loss of 1.6-l blood.

The relationship of the number of previous Caesarean deliveries to the presenting complaint, severity of vaginal bleeding, implantation site, internal cervical os distance and spontaneous abortion before 12 weeks was investigated. None of the variables were strongly influenced by the number of previous Caesarean deliveries.

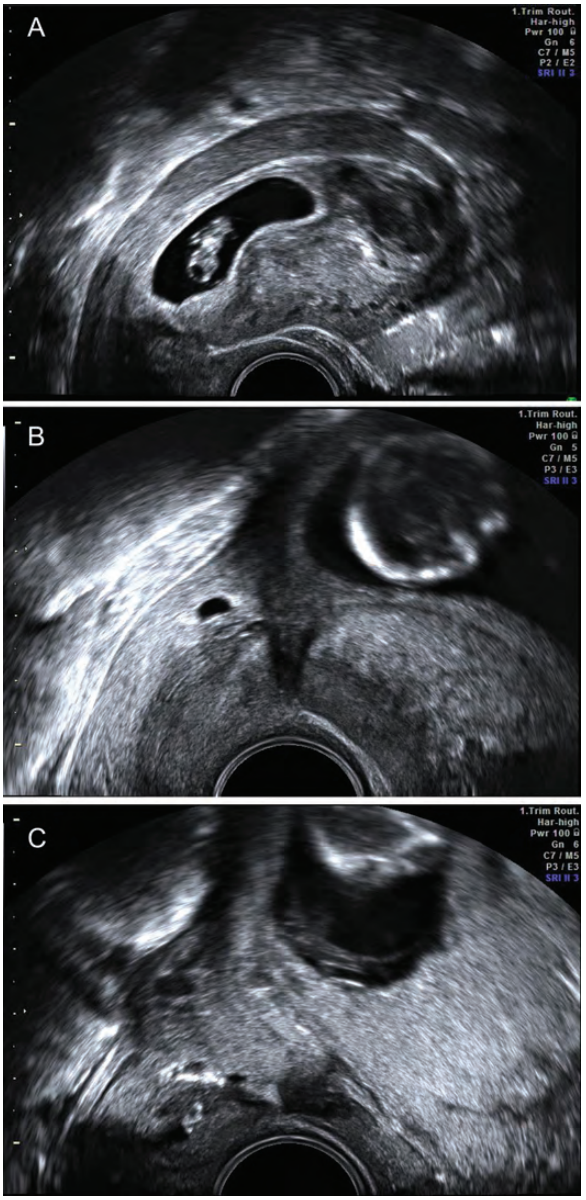


**Figure 6** (**A**–**C**) Follow-up scans of gestational sac crossing the Caesarean scar, A = 7 weeks, B = 20 weeks, C = 34 weeks of gestation.

## Discussion

We have shown that women attending an EPU with a CS on the uterus experienced more bleeding than women without a CS. This is of interest in view of recent ultrasound studies showing that CS scar with large hypoechoic segments are often associated with an absence of re-epithelialization and abnormal vascularization (Jauniaux and Jurkovic, 2012).

We also found differences in the site of gestational sac implantation. In the CS group they were mainly posterior whilst they were fundal in non-scarred uteri. Our data showed that anterior implantation occurs more often in women with more than one Caesarean than in women

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with only one Caesarean (25 versus 17%, respectively). These findings are similar to a previous case–control study we conducted to investigate the effect of CS scar on placental location and subsequent migration. The study population consisted of 2594 consecutive asymptomatic women who were examined at the time of their routine 11–14 week scan. We found significantly more posterior and fewer fundal placentas in the Caesarean group than the control group (Naji *et al.*, 2012a,b). However, we must exercise some caution when comparing results between these two studies with different study populations.

Our study also suggests that for women attending an EPU, a scarred uterus tends to be associated with a higher spontaneous abortion rate than women with no history of CS, although the difference was not statistically significant. Our data show a positive association between the number of previous Caesarean deliveries and early pregnancy loss. In other studies examining this issue, Hemminki (1986) did not allow for calculations of risk ratios in relation to the outcome of pregnancies after CS. However, in this study it was explained that if the proportion of women who had had a spontaneous abortion is recalculated using the denominator as a figure corrected by the mean number of pregnancies, an increased risk of spontaneous abortion is found (risk ratio 1.2), Douglas *et al.* (1963) also reported an increased risk of spontaneous abortion with a CS.

We acknowledge that a limitation of our study is the lack of a reference technique to verify the location of implantation. Although we have made every effort to ensure that pregnancies apparently implanting lower in the uterus or close to the scar are not simply pregnancies in the process of spontaneous abortion, it is possible that in some cases this may have been the case. A further potential criticism is that we did not examine scar dimensions and morphology, as our focus was on the location of the implantation site in relation to the scar, rather than the scar itself. Future studies looking at the impact of these factors on implantation would certainly be of interest.

We used subjective impression by the operator to describe the relationship between the implantation site and the previous CS scar. The subjective impression of the examiner was supported by the measurements of implantation to CS scar distance. The mean distance for the cases implanted away from the scar was 29.6 mm, while it was 14.7 and 3.8 mm for the ones implanted close and crossing the scar, respectively. There was no overlap in the distances between these groups. Our data showed that 22% of cases that implanted away from the scar miscarried before 12 weeks of gestation, compared with 55% for cases close to the scar and 88% when implantation was across the scar. This is potentially an important finding, although we must be cautious in view of the relatively small sample size. It is important to note that implantation sites that crossed the CS scar were not associated with heavy bleeding, although they were associated with spontaneous abortion. Furthermore, in the case that did not miscarry, the pregnancy survived to term and led to a live birth without catastrophic morbidity for the mother. It seems likely that there is a spectrum whereby the pregnancy may implant over the scar, with the degree of likely morbidity and the diagnosis of true CSP related to how far into the scar the pregnancy implants. This spectrum means that great care must be taken in order not to overdiagnose CSP as although minor scar involvement may lead to a level of pathological placentation, this may not be sufficient to justify termination of a pregnancy. Currently, the diagnostic performance of ultrasound to diagnose CSP is not known.

Several studies have described CS scars using ultrasound without establishing a relationship between the appearances of the scar and likelihood of CSP (Timor-Tritsch *et al.*, 2012).

Our results add further evidence to the hypothesis that the presence of a CS on the uterus impacts on the implantation site of a future pregnancy. We cannot say on the basis of our data whether the presence of a CS scar has any impact on the risk of spontaneous abortion in general, although this is a possibility that should be explored further. Furthermore, our analyses suggest it is not the mere presence of the scar that affects the risk of spontaneous abortion, but the closeness of the implantation site to the scar. Our observation that the implantation site may approach and cross the CS scar without implanting into the scar are novel and have implications for the diagnosis of CSP. Whilst criteria for diagnosis of CSP have been proposed the test performance of these have never been tested. Our findings suggest that there may be potential to over-diagnose CSP, a scenario likely to end in termination of the pregnancy. Similarly, although implantation into the scar led to a delivery complicated by serious bleeding, this may have been an outcome accepted by the mother had we been able to accurately quantify the risks based on the ultrasound findings. There is clearly a need for further studies to examine this. Given the relatively high CS rate worldwide, more women are embarking on pregnancies with a scar on their uterus, and CS scar-related morbidity will become increasingly important. Our data add further evidence that a CS scar impacts on future implantation and shows that there is likely to be a spectrum of pregnancy outcomes that mirrors the relationship of a CS scar and the implantation site of the index pregnancy.

## Authors' roles

O.N. was involved in conception and design of the study, ultrasound examinations, drafting the manuscript and final approval of the manuscript. L.W. was involved in statistical analysis, drafted the manuscript and manuscript reviews. A.S. was involved in data collection. Y.A. was involved in study design, acquisition of data and final approval of manuscript. S.S. was involved in acquisition of data, drafting of manuscript and final approval of manuscript. C.S. was involved in acquisition of data and final approval of manuscript. S.V.H. was involved in statistical analysis and final approval of manuscript. S.G.-M. was involved in manuscript review and final approval of manuscript. B.V.C. was involved in statistical analysis, critical revision of manuscript and final approval of manuscript. D.T. was involved in interpretation of data, critical revision of manuscript and final approval of manuscript. T.B. was involved in conception and study design, critical revision of manuscript and final approval of manuscript.

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## Conflict of interest

None declared.

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