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human reproduction **DEBATE**

Why do niches develop in Caesarean uterine scars? Hypotheses on the aetiology of niche development

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ABSTRACT: Caesarean section (CS) results in the occurrence of the phenomenon 'niche'. A 'niche' describes the presence of a hypoechoic area within the myometrium of the lower uterine segment, reflecting a discontinuation of the myometrium at the site of a previous CS. Using gel or saline instillation sonohysterography, a niche is identified in the scar in more than half of the women who had had a CS, most with the uterus closed in one single layer, without closure of the peritoneum. An incompletely healed scar is a long-term complication of the CS and is associated with more gynaecological symptoms than is commonly acknowledged. Approximately 30% of women with a niche report spotting at 6–12 months after their CS. Other reported symptoms in women with a niche are dysmenorrhoea, chronic pelvic pain and dyspareunia. Given the association between a niche and gynaecological symptoms, obstetric complications and potentially with subfertility, it is important to elucidate the aetiology of niche development after CS in order to develop preventive strategies. Based on current published data and our observations during sonographic, hysteroscopic and laparoscopic evaluations of niches we postulate some hypotheses on niche development. Possible factors that could play a role in niche development include a very low incision through cervical tissue, inadequate suturing technique during closure of the uterine scar, surgical interventions that increase adhesion formation or patient-related factors that impair wound healing or increase inflammation or adhesion formation.

Key words: Caesarean section / niche / scar / uterus / cervix / adhesion formation / surgical techniques / abnormal uterine bleeding / spotting

Introduction

Over the last few decades Caesarean section (CS) rates have continued to rise. In the UK the CS rate increased from 12 to 29% between 1990 and 2008 (Betran *et al.*, 2007). In the USA in 2011 one in three women delivered by CS, whereas in China the CS rates have even risen from 2% in 1985 to 36–58% in 2010 and in Brazil from 15% in 1970 to even 80% in the private sector in 2004 (Barros *et al.*, 2011; Deng *et al.*, 2014; Feng *et al.*, 2014; Osterman and Martin, 2014). There is no discussion that a CS is a lifesaving procedure for some women, for example for women with placenta praevia or truly obstructed labour, or for babies with proven distress either antenatal or intrapartum. Also, women with a breech pregnancy or a twin pregnancy are likely to benefit from a CS, albeit that the large majority of them will do well without a CS (Hofmeyer *et al.*, 2015; Roberts *et al.*, 2015; Vlemmix *et al.*, 2015). The World Health Organization estates the optimal CS rate at 15% (Gibbons et al., 2010).

The increasing CS rate has stimulated an interest in the potential long-term morbidity of CS scars (Diaz *et al.*, 2002; Silver, 2010; Clark and Silver, 2011).

In the last decades we became aware of gynaecological symptoms after a CS, such as postmenstrual spotting, dysmenorrhoea, chronic pelvic pain and dyspareunia (Wang *et al.*, 2009; Bij de Vaate *et al.*, 2011; van der Voet *et al.*, 2014a).

Already in 1999 it was postulated that these symptoms could be related to an incompletely healed uterine scar, also called a niche. Thurmond *et al.* postulated the hypothesis that a niche in the Caesarean scar could be a cause of abnormal bleeding due to the collection of menstrual blood in a uterine scar defect causing postmenstrual spotting (Thurmond *et al.*, 1999).

Later prospective cohort studies reported spotting in ~30% of women with a niche at 6–12 months after their CS compared with 15% of women without a niche after CS.

Morphological 'abnormalities' in the Caesarean scar can be visualized using transvaginal sonography (TVS), gel or saline instillation sonohysterography (GIS or SIS) or hysteroscopy (Osser *et al.*, 2010; Bij de Vaate *et al.*, 2011; van der Voet *et al.*, 2014a). A wedge-shaped defect in the uterine wall following CS was first described using hysterosalpingography in 1961 (Poidevin, 1961). The terminology used to describe these scar

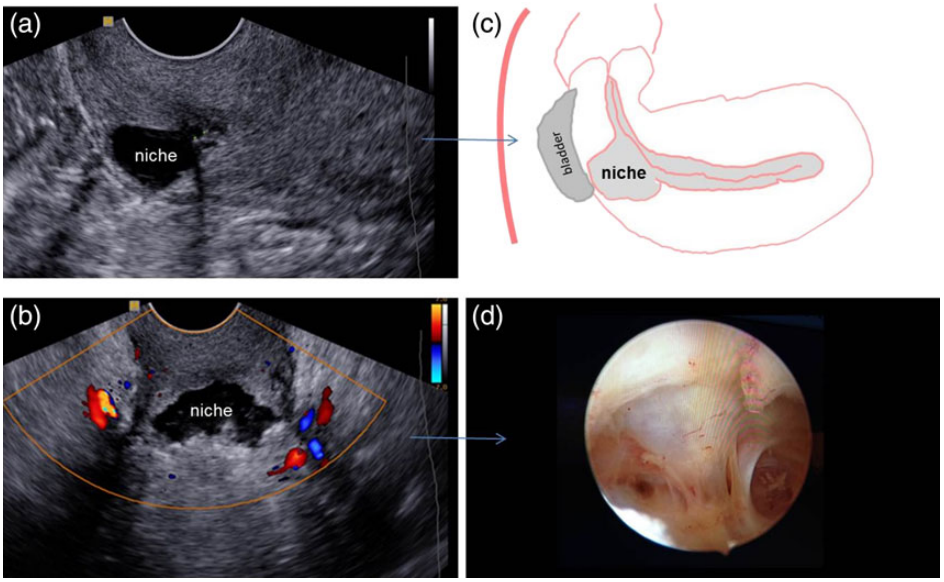

Figure 1 Image of a niche using transvaginal ultrasound in mid-sagittal and transversal plane and a schematic diagram of a niche and hysteroscopic image. (**a**) Mid-sagittal plane; (**b**) transversal plane; (**c**) schematic diagram of a niche; (**d**) niche seen by hysteroscopy, the internal os is out of the scope of this picture.

abnormalities, scar defects, or niches in the uterine scar, differs in the various publications on this subject (Osser *et al.*, 2009; Bij de Vaate *et al.*, 2011; Naji *et al.*, 2012). We prefer to use the term 'niche', which was introduced by Monteagudo *et al.* in 2001 (Monteagudo *et al.*, 2001). The term 'niche' describes the presence of a hypoechoic area within the myometrium of the lower uterine segment, reflecting a discontinuation of the myometrium at the site of a previous CS (Bij de Vaate *et al.*, 2011; Naji *et al.*, 2012) (Fig. 1).

On further study, a niche appears to be frequently present after a CS. Using GIS or SIS, niches were identified in the scar in more than half of the women who had had a Caesarean delivery. Niches were defined as indentations of the myometrium of at least 2 mm (Bij de Vaate *et al.*, 2011; van der Voet *et al.*, 2014a). Large niches occur less frequently, with an incidence varying from 11 to 45% dependent on the definition used (a depth of at least 50 or 80% of the anterior myometrium, or the remaining myometrial thickness $\leq$2.2 mm when evaluated by TVS and $\leq$2.5 mm when evaluated by sonohysterography) (Bij de Vaate *et al.*, 2011; Bij de Vaate *et al.*, 2014; van der Voet *et al.*, 2014a). In the above mentioned cohort studies, more than 95% of the patients' uteri were closed in one single layer, without closure of the peritoneum (unpublished data). In particular this closing strategy may increase niche development. Several therapies have been reported in order to treat niche-related symptoms (van der Voet *et al.*, 2014b), however it is important to underline that diagnostics and treatment should only be considered in case of symptomatic women in order to avoid 'too much medicine' (Moynihan and Smith, 2002).

In addition to the gynaecological symptoms niches may, in theory, impair subsequent fertility. Intrauterine fluid during the ovulation, or mucus and blood accumulation in the cervix in association with a niche may hamper the penetration of sperm cells or impair embryo implantation. A recent meta-analyses including 85 728 women reported that a CS on average reduced the probability of subsequent pregnancy by 10% [relative risk (RR) 0.91, 95% confidence interval (CI) (0.87–0.95)] in comparison to a vaginal delivery (Gurol-Urganci *et al.*, 2013). Most of the 16 included studies found that fertility was reduced after a CS. Studies that were more robust in terms of design and quality and those that controlled for maternal age exerted a smaller but significant effect. None of these studies evaluated the relation between subsequent fertility and the presence of niche development. These authors conclude in a later retrospective cohort study including 1 047 644 women, that there is no, or a slight, effect of CS on future fertility (Gurol-Urganci *et al.*, 2014). The size of the effect depended on the type and indication for CS. Compared with vaginal delivery, subsequent fertility was 4% lower after CS for breech presentation (HR 0.96 CI 0.94–0.98), but SC for other indications reported a 19% lower fertility (adjusted hazard ratio (HR) 0.81, 95% CI 0.78–0.83), and 9% lower fertility in case of emergency Caesarean (adjusted HR 0.91, 95% CI 0.90–0.93). Even if the true reduction in fertility would be closer to 4% than to 19%, this has high impact in view of the high numbers of CS performed globally. The association between a niche and future fertility should be subject to future study. The long-term follow-up of the CORONIS trial will hopefully provide more insight in this topic (Abalos *et al.*, 2013).

The presence of a niche may be associated with obstetric complications in future pregnancies. A Caesarean scar pregnancy is a pregnancy located at the site of a niche, outside the uterine cavity and is completely surrounded by myometrium or fibrous tissue of the scar. Although this is very rare event, it is highly relevant to recognize this type of ectopic pregnancy. It can lead to uterine scar rupture and life threatening haemorrhage, in particular if a vacuum curettage is performed in case it is misdiagnosed as an (ongoing) miscarriage (Diaz *et al.*, 2002; Fylstra, 2002; Jurkovic *et al.*, 2003; Seow *et al.*, 2004; Litwicka and Greco, 2013). Awareness in combination with proper sonographic evaluation is important before a curettage is considered to prevent unneeded complications (Timor-Tritsch *et al.*, 2012). Other obstetric

complications include malplacentation, and possibly increased risk of unsuccessful vaginal birth after CS resulting in an intrapartum (emergency) CS (Clark *et al.*, 1985; Naji *et al.*, 2013).

Given the association between a niche and gynaecological symptoms, obstetric complications (such as niche pregnancy and malplacentation) and potentially with subfertility, it is important to elucidate the aetiology of niche development after CS in order to develop preventive strategies. Several previous studies tried to identify potential risk factors for niche development, as summarized by Bij de Vaate *et al.* in a systematic literature review (Bij de Vaate *et al.*, 2014). Factors that were associated with niche development were divided into four domains: (i) factors related to development of the lower uterine segment or level of the uterine incision, (ii) factors related to uterine closure technique, (iii) factors possibly related to wound healing and (iv) others. However current evidence on niche development is limited by inconsistencies in used definitions, diagnostic methods and study design (Bij de Vaate *et al.*, 2014).

Based on both the limited available evidence in combination with our observations during sonographic, hysteroscopic and laparoscopic evaluations of niches we have postulated hypotheses on niche development. Our hypotheses can be divided into surgery-related factors and patient-related factors. In our paper we focus on surgery-related factors since these could be easily modified and studied in future RCTs.

Surgery-related factors

(1) Low (cervical) location of the uterine incision during a CS
(2) Incomplete closure of the uterine wall, due to single-layer, endometrial saving closure technique or use of locking sutures.
(3) Surgical activities that may induce adhesion formation (i.e. non-closure of peritoneum, inadequate haemostasis, applied sutures, use of adhesion barriers).

Patient-related factors

(1) Factors that possibly hamper normal wound healing and related angiogenesis.

Hypotheses

Hypothesis 1: Cervical location of the uterine incision induces impaired wound healing

Our first hypothesis is that low incisions through cervical tissue, containing mucus-producing glands, hampers wound healing. Local mucus formation may induce dehiscence of the approximated myometrium layers. In addition, local mucus accumulation in communicating spaces may induce the formation of large 'retention cysts' or may increase the size of a niche over time.

During combined hysteroscopic and sonographic evaluations we became aware of the fact that large niches are often located in the (lower) uterus. These niches mostly contain a lot of mucus or are closely related to retention cysts or ovula of Nabothi (Fig. 2). Vaginal discharge of brown mucus is a frequent symptom in women with large niches. This hypothesis is in line with the results of two prospective cohort studies. One study reported very low uterine incisions to be an independent risk factor for the development of large niches (Osser *et al.*, 2010). Others reported a CS performed in active labour, after the cervix has effaced and has become part of the uterine wall, to be associated with a higher prevalence of niches (Zimmer *et al.*, 2004). However, more evidence is needed to confirm the hypothesis that the cervical location of the uterine scar impairs wound healing. Another issue is the routine creation of a bladder flap by opening the utero-vesical fold of the peritoneum. Dissection of the bladder is commonly performed to keep the bladder dome out of the surgical field, but might also influence the location of the uterine incision during CS. The necessity of this step has only recently begun to be examined, and there is some evidence that in routine cases the creation of a bladder flap can be omitted safely (Hohlagschwandtner *et al.*, 2001; Tuuli *et al.*, 2012; O'Neill *et al.*, 2014). However, niche development has not been an outcome in any of these studies. The need for the dissection of the bladder during a first CS can easily be studied in a randomized trial (randomization between bladder dissection or no bladder dissection). The effect of the location of the incision in the uterus might be more difficult to study because marking of the cervical- corporal junction is difficult in effaced cervices. Proper training, for example in combination with electronic learning could be used to prevent incisions through the lower cervix.

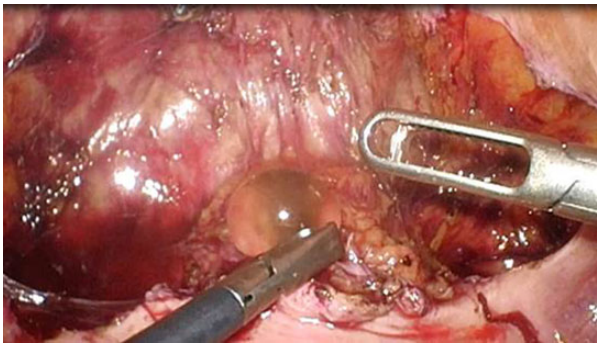

Figure 2 Laparoscopic view on a mucus-containing large niche that is located in the lower cervix. Mucus is expelled during a laparoscopic niche resection after dissection of the bladder and opening of the niche.

Hypothesis 2: Incomplete closure of the uterine wall

The second hypothesis is that partial closure of the uterine wall during CS, due to unintentional omission of closing the deeper muscular layer, may subsequently lead to a disrupted myometrium and thus niche development. Potential causes include superficial closure due to non-perpendicular (tangential) sutures and endometrial saving techniques (Fig. 3a).

The applied technique of closing the uterus has continued to change over the years (Pandit and Khan, 2013). In the UK, double-layer closure is advocated, and they concluded from earlier studies that effectiveness and safety of single-layer closure of the uterine incision was uncertain (Nice guideline, 2013), while in several other countries including the Netherlands and Belgium most gynaecologists changed from double-layer to single-layer closure of the uterus. In a recent survey performed in the Netherlands in 2015, among 528 gynaecologists and residents it was confirmed that the vast majority (92.2%) applies single-layer closure using multifilament continuous (96.2%) unlocking (87.1%)

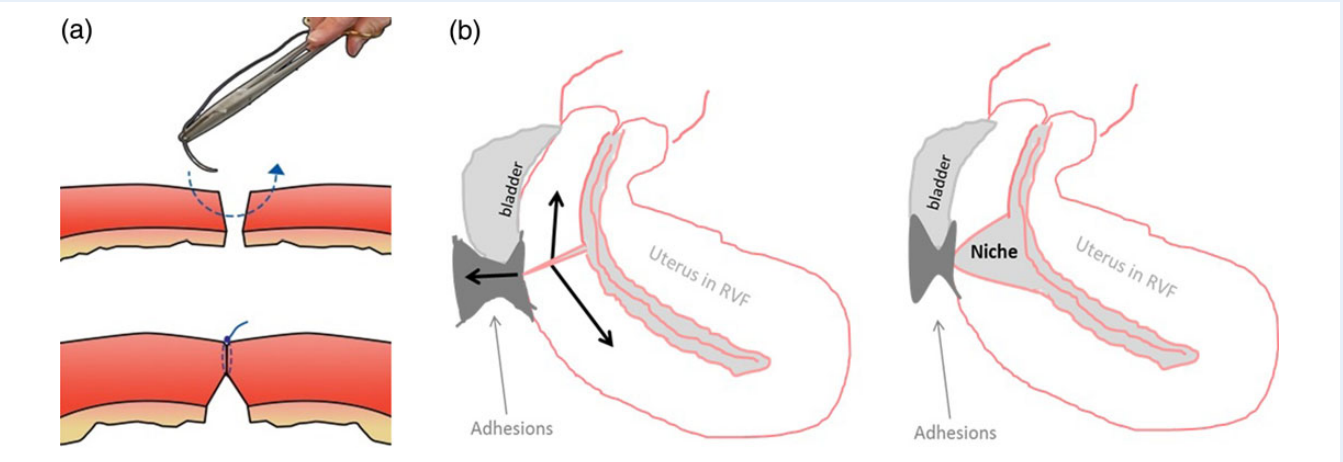

Figure 3 Schematic diagram of incomplete closure of the myometrium and counteracting forces on the uterine scar due to the retraction of adhesions between the scar and the abdominal wall in a retroflected uterus. (**a**) Single-layer closure of the uterus may increase niche formation due to greater risk of incomplete closure. (**b**) Counteracting forces on the Caesarean section uterine scar, due to retraction of adhesions between the uterine scar and the abdominal wall in a retroflected uterus, may impair wound healing and increase the formation of niches.

sutures. Approximately half of the gynaecologists apply endometrial saving techniques. The peritoneum was not closed by 86.2% of the gynaecologists (unpublished data, 2015).

In the last decade two randomized trials were published on short-term outcomes after different surgical techniques for CS: the CAESAR and CORONIS trials (CORONIS trial, 2007; CAESAR trial, 2010). These trials evaluated different surgical interventions in >3000 patients (CAESAR) and >15 000 patients (CORONIS). The following interventions were studied: single- versus double-layer closure of the uterine layer, closure versus non-closure of the peritoneum (pelvic and parietal), liberal versus restricted use of a subrectus sheath drain, blunt versus sharp abdominal entry; exteriorization of the uterus for repair versus intra-abdominal repair and chromic catgut versus polyglactin-910 for uterine repair (CORONIS trial, 2007). Apart from a higher incidence of blood transfusion (secondary outcome) using catgut versus polyglactin-910 for uterine repair, no significant differences between any of the interventions studied were found in maternal or fetal outcomes during the first 6 weeks. This led to freedom for surgeons to choose their own technique for CS.

Dodd *et al.* included 27 RCTs in a Cochrane review (2014) evaluating surgical techniques for uterine incision and uterine closure; sharp versus blunt uterine entry, absorbable sutures versus auto-suture devices, direction of blunt dissection: transverse versus cephalad-caudal, different suture materials for closure of the uterine incision, continuous suture versus interrupted suture and single versus double layer closure (Dodd *et al.*, 2014).

No differences were found for short-term outcomes such as febrile morbidity, risk of blood transfusion or other reported clinical outcomes. However, long-term outcomes of various closuring techniques in terms of fecundity, risk of uterine rupture in future pregnancies and possible increased risk of symptoms related to niches have not been studied sufficiently yet. None of earlier trials reported on menstrual disorders (prolonged bleeding, spotting or menstrual pain), dysmenorrhoea, other gynaecological symptoms or on secondary fertility problems after a CS.

So far, only a few studies evaluated the effect of uterine closure techniques on niche prevalence. Roberge *et al.* included 20 RCTs in a systematic review (2014) to evaluate particularly single- versus double-layer suturing in relation to adverse outcomes and prevalence of uterine scar defects (niches) (Roberge *et al.*, 2014). As also reported in earlier reviews, no differences were found in peri-operative outcomes. Nonetheless, single-layer closure was associated with shorter operative time (−6.1 min). Three studies evaluating single- versus double-layer suturing including a total of 1151 patients evaluated the prevalence of dehiscence at repeat CS (Hauth *et al.*, 1992; Chapman *et al.*, 1997; Yasmin *et al.*, 2011). In the meta-analyses only 187 patients could be included, with a RR of dehiscence of 2.38 (95%, CI 0.63–8.96). No significant difference in the risk of uterine scar defect was found with single-layer closure (193 patients; RR 0.53; 95% CI, 0.24–1.17; $P = 0.12$) compared with double-layer closure. However, single-layer closure resulted in a significantly thinner residual myometrial thickness compared with double-layer closure (240 patients; weighted mean difference of −2.6 mm; 95% CI, −3.1 to −2.2; $P < 0.001$), evaluated by ultrasound or hysterosalpingography 6–12 weeks after the CS. There are clues that double-layer closure could reduce the risk of uterine rupture (Bujold *et al.*, 2002, 2010; Durnwald and Mercer, 2003). Bujold *et al.* analysed 96 cases of uterine rupture in a multicentre, case–control study and concluded that double-layer closure of the uterus, compared with single-layer, reduces the risk of uterine rupture in a future pregnancy by half (Bujold *et al.*, 2010). However, it can be questioned if the sample size was large enough to study this outcome. Yazicioglu *et al.* investigated two different techniques for uterine closure after secondary and elective CS in a prospective cohort study including 78 patients (Yazicioglu *et al.*, 2006). Fewer niches were reported in this study after single full thickness uterine closure compared to split thickness uterine closure, which excluded the endometrium.

Another theory regarding uterine closure relates to locked versus unlocked sutures. Some studies suggest that the locked modification of a single-layer suture may increase the risk of uterine rupture due to an

increase in tissue hypoxia and subsequent deficient healing (Roberge *et al.*, 2011).

One RCT and a prospective longitudinal study compared locked to unlocked sutures (Yasmin *et al.*, 2011; Ceci *et al.*, 2012). Yasmin *et al.* showed decreased myometrial thickness (60 patients; mean difference, −2.5; 95% CI, −3.2 to −1.8; $P < 0.001$) and increased blood loss (60 patients; mean difference, 45.0 ml; 95% CI, 21.6–68.4; $P < 0.001$) with locking of the first layer. Ceci *et al.* reported no difference in terms of proportion of scar defect at ultrasound 6–12 months after the CS (55 patients; RR, 1.16; 95% CI, 0.97–1.40; $P = 0.11$), using continuous locked single-layer compared with interrupted, unlocked, single-layer suture. However, continuous, locked, single-layer closure was coupled with a larger scar defect ($P < 0.001$) on sonographic evaluation.

Thus, double-layer uterine closure using non-locking sutures may result in a thicker residual myometrium and potentially a lower prevalence of niches. However, to date, we have to conclude that the optimal closuring technique in terms of the prevention of niches and related symptoms has not been elucidated and requires additional studies, preferably RCTs with long-term follow-up including structural sonographic evaluation.

Hypothesis 3: Surgical activities that may induce adhesion formation and as a consequence induce impaired wound healing due to counteracting forces on the uterine scar

Our third hypothesis relates to adhesion formation between the CS scar and the abdominal wall.

The reported prevalence of adhesions in women during their second CS is 12–46% and 26–75% during their third CS (Makoha *et al.*, 2004; Morales *et al.*, 2007; Tulandi *et al.*, 2009; Walfisch *et al.*, 2014).

During our laparoscopic niche reconstructions that are performed under hysteroscopic evaluation, we find dense fibrotic adhesions attached at the top of the wedge-shaped niches in the majority of our cases (Fig. 4). Our hypothesis is that adhesions may induce niche development due to retraction of the scar tissue, which pulls on the uterine scar towards the abdominal wall. This force is opposite to the direction of the retracting tissue in the uterine scar itself, that is required for optimal approximation of the myometrium layers and healing (Figs 3b and 5). These counteracting forces may even be increased by gravity on the corpus in a retroflexed uterus.

An interesting observation is that a lot of our patients seen for laparoscopic niche repair of large symptomatic niches have retroflected uteri. This thought is supported by two studies that indeed report a higher prevalence of large niches in women with retroflected uteri, although the uterine position before the CS was not registered in these studies (Osser *et al.*, 2009; Bij de Vaate *et al.*, 2014). Therefore, the question remains, what was first, a retroflected uterus which caused the scar to heal improperly or was the retroflection the result of the niche itself, due to the lack of support of the corpus by the incomplete closure of the uterine wall?

In theory, several factors that influence adhesion formation after CS can be postulated. In general it is known that factors such as inadequate haemostasis, inflammation due to infection, tissue ischaemia, tissue devascularisation and tissue manipulation can cause formation of adhesions (Awonuga *et al.*, 2011; Hellebrekers and Kooistra, 2011).

It is also known that surgical techniques can contribute to the development of adhesions.

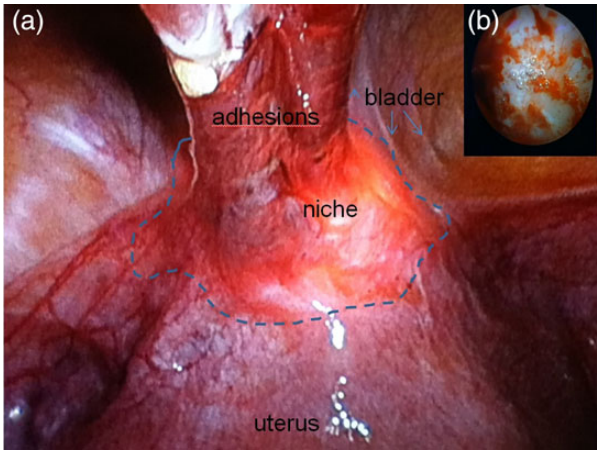

Figure 4 Laparoscopic image of a uterus with a large niche, illumination of the hysteroscopic light in the niche can be seen directly under the adhesions attached to the niche. Adhesions between the niche and the abdominal wall seen during laparoscopy (**a**), owing to the diaphany of the combined hysteroscopy it can be seen that the adhesions are located at the deepest point of the niche. Hysteroscopic image of the combined of a part of the large niche surface be seen in (**b**).

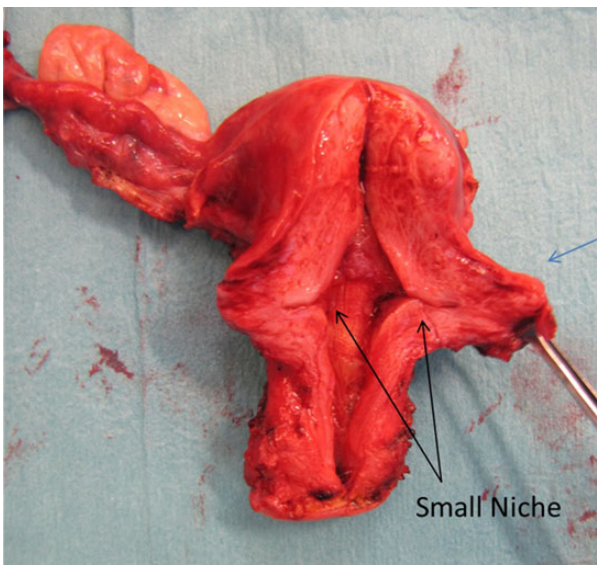

Figure 5 Macroscopic image of a uterus with a niche, removed by laparoscopy because of abnormal uterine bleeding and dysmenorrhoea. Note that the adhesions are located at the deepest point of (a relatively small) niche.

The type of suturing material used may play a role. Apart from the higher incidence of blood transfusions using catgut versus polyglactin-910 in the CORONIS study, we are not aware of studies comparing different suture material during CS on the development of adhesions (CORONIS trial, 2007).

Another potential issue is the effect of peritoneal closure. Non-closure of the peritoneum, in particular in combination with the

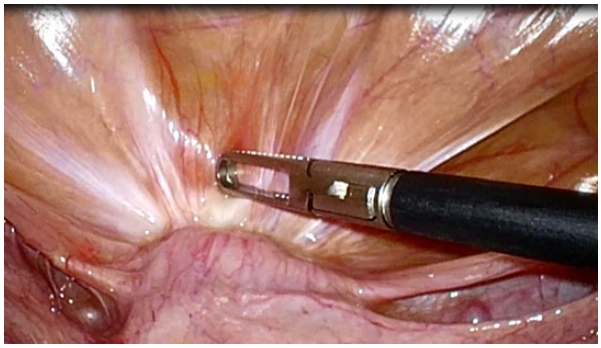

Figure 6 Laparoscopic view on adhesions between the lower uterine segment and the bladder at the site of a niche.

development of a bladder flap that is not sutured, results in two effaced non-peritonealised areas, facilitating adhesion between the bladder and the uterus (Fig. 6).

Based on several studies, including a systematic review by Cheong *et al.* including three studies ($n = 249$) (two RCTs and one prospective non-randomized study), it was concluded that non-closure of the parietal peritoneum is associated with more adhesion formation than closure (Cheong *et al.*, 2009; Shi *et al.*, 2011). Subsequent to these publications another large controlled trial including over 500 women found no significant differences in adhesions on inspection at the repeat CS ($n = 97$) (Kapustian *et al.*, 2012). However, verification bias cannot be excluded, as scar evaluation was not an outcome and especially patients with large niches might have had fertility problems. A proper RCT with niche formation and related symptoms as a primary or secondary outcome is needed to evaluate the necessity of peritoneal closure during a CS.

An alternative method to reduce adhesion formation is the use of adhesion barriers.

Three studies reported a reduction in adhesion rates at repeat CS after the use of sodium hyaluronate-carboxycellulose or Interceed compared with a control group without the use of an adhesion barrier during CS (Fushiki *et al.*, 2005; Chapa *et al.*, 2011; Plante *et al.*, 2014). However none of these studies were RCTs and samples sizes were small.

No differences in adhesion formation were reported in a large ($n = 517$) retrospective comparative cohort study and one large RCT ($n = 753$) comparing the use of sodium hyaluronate-carboxycellulose with a control group without an adhesion barrier (Edwards *et al.*, 2014; Kiefer *et al.*, 2014). In the Kiefer *et al.* (2014) study, two cases of uterine dehiscence during subsequent CS were reported after barrier use compared with one in the control group (Kiefer *et al.*, 2014). None of other studies evaluated the effect of adhesion barriers on niche formation or related symptoms.

There is a need for well-controlled, randomized clinical studies investigating the use of adhesion barriers during CSs on subsequent niche development and future fertility and pregnancy outcomes.

Hypothesis 4: Patient or disease related factors that impair wound healing

Individual differences in wound healing exist. However, it remains puzzling why some of our patients (around 5%) develop a recurrent niche, despite proper laparoscopic surgical reconstruction, confirmed by simultaneously performed hysteroscopic evaluation. This suggests an individual predisposition for impaired wound healing caused by factors still unknown. In an animal model it has been demonstrated that genetic predisposition may affect histological and biomechanical wound healing of artificial myometrial defects (Buhimschi *et al.*, 2010). Some studies in humans report an association between niche development and BMI, preeclampsia or hypertension (Osser *et al.*, 2009). However the mechanism of action remains unclear. Is it the disease itself that hampers proper wound healing or does it affect haemostasis, inflammation and related adhesion formation? Additional studies, in particular translational studies, are needed to explore these items.

Discussion

Defects of the uterine scar after a CS seem to constitute a rapidly increasing problem. Since 2002 the British Medical Journal series 'Too much medicine' campaign has shed light on the problem of unnecessary or excessive health care including overdiagnosis, overtreatment and medicalization. Over the past centuries, the number of CSs has increased without scientific justification (Johanson *et al.*, 2002). Obviously, the potential issue of the niche could be prevented if the number of CSs could be controlled, which can be established by a control over the number of first Caesarean deliveries (Wagner, 2001; Spong *et al.*, 2013). Once a decision is made to perform a CS it is important to know which factors impair proper wound healing in order to prevent niche formation. Our paper needs to be seen as an attempt to guide future research in order to elucidate the aetiology of niche development. Only after proving the effectiveness of specific CS techniques (i.e. single- or double-layer closure, creation of a bladder flap or not, closuring of the peritoneum, relatively high uterine incision in case of active labour), will we be able to define the optimal way to perform a CS and to develop proper training programmes.

Conclusion

We have identified mechanisms through which niches can develop in uterine Caesarean scars and can cause complaints for women long after their CS. It is important to address these complaints, and evaluate diagnostic, therapeutic and preventive strategies. It is also important, however, to be critical on our CS rate in obstetric practice. Women who deliver vaginally will never develop a niche.

Authors' roles

All authors made substantial contributions to this manuscript. They all participated in the conception and drafting of the manuscript including the interpretation of data from literature and (critically) revised this manuscript. All authors approved the final version to be published.

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Conflict of interest

There were no conflict of interests for this article other than the received grants by ZonMw.

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