Zakherah *et al.*
Middle East Fertility Society Journal (2024) 29:29
https://doi.org/10.1186/s43043-024-00185-7

Middle East Fertility Society Journal

REVIEW

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Navigating uterine niche 360 degree: a narrative review

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Abstract

Background The increasing prevalence of cesarean section (CS) deliveries globally has sparked apprehension regarding potential long-term complications, notably the emergence of uterine niches. CS results in a scar that in certain patients, inadequate healing of that scar results in the development of a uterine niche. While most small niches show no symptoms, large cesarean scar niches in nonpregnant women can give rise to cesarean scar disorder syndrome. This syndrome is characterized by abnormal uterine bleeding, dysmenorrhea, and secondary infertility. In pregnant women, the presence of substantial niches may be linked to potentially life-threatening complications, including cesarean scar dehiscence, uterine rupture, placenta accreta spectrum disorders, placenta previa, and cesarean scar ectopic pregnancy.

Main body Given the potential dangers associated with uterine niche occurrence, numerous studies in recent years have delved into the concept of cesarean scar niche, exploring its risk factors, diagnostic approaches, and treatment options. Various diagnostic modalities, such as two- or three-dimensional transvaginal ultrasonography, two- and three-dimensional sono-hysterography, hysterosalpingography, hysteroscopy, or magnetic resonance imaging, can be employed to detect uterine niches. However, none of these diagnostic methods is universally accepted as the "gold standard," and there remains a lack of unequivocal guidelines on certain aspects related to the diagnosis of cesarean scar niche. These niches, characterized by hypoechoic regions within the myometrium at the site of a previous CS scar, pose diagnostic complexities and provoke inquiries into their prevalence, factors influencing their development, clinical presentations, and appropriate therapeutic approaches.

Conclusion As CS rates rise, this review aims to understand and address uterine niches and mitigate their impact on maternal health and reproductive outcomes.

Keywords Uterine niche, Isthmocele, Cesarean section, Cesarean scar disorder

Background

The global cesarean section (CS) rate is rising, surpassing the WHO-recommended 10–15% of total births [1]. Reportedly, Europe has a 25% CS rate, South America 42%, Latin America 40%, and Egypt 50%, raising concerns about potential long-term complications [2]. One such consequence is the development of a uterine niche, also known as an isthmocele or CSD (cesarean scar defect), characterized by a discontinuity or defect in the myometrium at the site of a prior uterine scar [3].

Main text

Definition

"Niche" as medical term describes a hypoechoic area within the myometrium at the site of a prior CS scar, indicating myometrial discontinuity [4]. According to the European Niche Taskforce, it is defined as an indentation of at least 2 mm in the myometrium at the site of

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a previous CS scar, measured by transvaginal ultrasound (TV/US) [1].

Prevalence

The prevalence of uterine niches varies based on detection techniques and diagnostic criteria [5]. Tulandi and Cohen's systematic review reported niche prevalence between 24 and 70% via TV/US and 56 and 84% through sono-hysterography in women with one or more CS. In symptomatic women, niche prevalence tends to be higher. Armstrong et al.'s case–control study reported a 24% prevalence with transvaginal ultrasound in women with prior CS [6]. Regnard et al.'s study, involving 33 women with prior CS, found a 60% prevalence using saline contrast sono-hysterography performed at least 3 months after the last CS [7].

In a prospective cohort study by Bij de Vaate involving 225 women with prior CS, examination by TV/US and gel instillation sonography (GIS) 6–12 months after the last CS revealed a uterine niche prevalence of approximately 24% with TVS and 56% with GIS [8]. LF van der Voet and colleagues analyzed the incidence of uterine niche 6 to 12 weeks after CS using TV/US and GIS. TV/US evaluation showed a niche in 49.6% of 263 women, while GIS evaluation demonstrated a niche in 64.5% [9].

Risk factors and mechanism of niche formation

Vervoort has proposed hypotheses on niche development based on limited evidence. Surgical factors, such as the site uterine incision and technique of closure during CS, may contribute. Additionally, certain surgical habits, like not to close the peritoneum and inadequate hemostasis, could lead to adhesion development. Patient-related hypotheses focus on factors that may hinder normal wound healing and the angiogenesis that it necessitates [4].

The *first hypothesis* suggests that a low uterine incision within cervical tissue may impede wound healing due to mucus-producing glands in the cervical tissue. Local mucus production can lead to myometrial layer dehiscence, retention cyst formation, or enlargement of preexisting niches. Larger niches, frequently observed at the lower uterus during hysteroscopy and ultrasound, are associated with abundant mucus or Nabothian retention cysts [4].

Two prospective cohort studies support this hypothesis. One indicates that extremely low uterine incisions are a significant risk factor for impaired healing and the formation of large niches [10]. Another study links CS during the active phase of labor, when the cervix is part of the birth canal, to an increased incidence of niche formation [11].

To further confirm the impact of uterine scar placement in the cervix on incision healing, additional evidence is needed. The routine creation of a bladder flap during CS, intended to move the bladder from the operative field, is a concern as it may affect the uterine incision level. Studies are beginning to explore whether this step can be safely omitted, but its impact on niche formation is yet to be investigated [12]. However, existing studies did not specifically focus on niche formation, and studying the effect of incision site in the uterus can be challenging, particularly when the cervix is significantly effaced [4].

Table 1 illustrates some studies that discussed the relationship between the location of uterine incision and uterine niche (Appendix A).

The *second hypothesis* proposes that incomplete closure of the entire thickness of the uterine incision after CS may lead to niche formation. Failure to close the deep muscular layer, often due to tangential sutures and decidual-sparing techniques, can disturb the myometrium and contribute to niche development [4].

Guidelines recommend double-layer closure, as previous studies found the efficacy and safety of single-layer closure undetermined [13]. However, in several countries, many gynecologists opt for single-layer closure over double-layer closure [4]. Studies investigating the impact of repair techniques on uterine niche prevalence aimed to answer questions about differences between single and double-layer closure, the effect of locking sutures compared to non-locking sutures, and whole thickness versus split-thickness uterine closure.

A systematic review of these topics revealed variable and interlacing results. There was no statistically significant difference in niche incidence ($p=0.58$), but long-term residual myometrium thickness was slightly thicker following double-layer repair ($p=0.06$) [14].

Table 2 illustrates the studies that detected the effect of different repair techniques of uterine incision on Niche formation (Appendix A).

The *third hypothesis* suggests that certain surgical habits may lead to adhesion formation, delaying the healing of the uterine incision. Adhesions between the uterine scar site and the anterior abdominal wall can exert opposing forces on the edges of the uterine incision, pulling them away from the scar line. This counteracts the necessary retraction of uterine scar tissue for proper alignment of myometrial layers and scar healing. Gravity acting on a retroflexed uterus may intensify these opposing forces. Notably, individuals with large symptomatic niches undergoing laparoscopic correction often have retroflexed uteri [4].

The *fourth hypothesis* involves patient-related factors or underlying diseases that may delay wound healing.

Approximately 5% of patients may experience recurring niches even after laparoscopic surgical reconstruction, suggesting a genetic predisposition for poor wound healing influenced by unidentified variables. Animal models show genetic disposition can impact the histology and biomechanical healing of artificially induced myometrial defects. Some human trials note correlations between niche formation and BMI, and hypertensive disorders (including preeclampsia), but the exact mechanisms remain unknown [4].

Clinical presentation

The majority of uterine niches are asymptomatic and often discovered incidentally during ultrasound [2]. While many women may be asymptomatic, uterine niche has been linked to various symptoms including bleeding (postmenstrual or intermenstrual), pain (dysmenorrhea or chronic pelvic pain), and reproductive issues (secondary infertility). Other reported symptoms include bladder dysfunction, scar abscess, and potential effects on in vitro fertilization (IVF) implantation [2, 15]. Niche-related obstetric consequences, such as CS scar pregnancy, abnormal placentation (previa- accreta), and scar dehiscence (partial or complete leading to rupture uterus), have also been described. Further research is needed for conclusive evidence on certain symptoms [2].

Gynecological issues

(1) Abnormal uterine bleeding in the following forms:

(a) Post-menstrual spotting

Postmenstrual spotting (PMS) is a characteristic symptom of uterine niche, occurring in approximately 30–55% of women 6 to 12 weeks after cesarean section (CS) delivery. PMS is defined as ≥ 2 days of spotting inter-menstrual or following menstruation. The cause is attributed to accumulated menstrual blood in the niche, where it hangs until gradually released due to restricted flow and weak contractility of fibrosed muscle [2].

In a prospective study 1 year post-CS, 20% of women with uterine niche experienced PMS, compared to 8.3% without, with a 3.34 odds ratio (OR) for larger niches [16]. The size of the defect correlates with the duration of postmenstrual spotting. Pathological findings of free erythrocytes in scar tissue suggest local blood formation within the niche, causing occasional spotting. Regardless of the cause, blood presence in the niche increases mucus secretion, contributing to PMS [2].

Uterine niche-related bleeding can be classified as AUB-N (abnormal uterine bleeding—niche) according to the PALM-COEIN terminology for abnormal uterine bleeding by FIGO, as it has not been specifically defined [15].

(b) Intermittent spotting

Predicting the causes of postmenstrual versus intermenstrual spotting in a uterine niche is challenging. The hypothesis suggests that blood production within the niche, indicated by the presence of free erythrocytes within the scar, may contribute to intermenstrual spotting [15].

(2) Pain

Women with uterine niche may experience various forms of pain. The most common is cyclic pain (dysmenorrhea) affecting 40–50%, followed by non-cyclic pelvic pain or chronic pelvic pain in 35%, and pain during sexual intercourse (dyspareunia) in 18%. Suprapubic pain is also reported [16]. The size of the uterine niche correlates with pelvic discomfort and dysmenorrhea. Anatomical disturbances in the lower uterine section, fibrosis, and inflammatory infiltration are linked to these pain complaints [2].

(3) Midcycle intrauterine fluid accumulation, abnormal vaginal discharge

In about 45% of women, uterine niche-related pain may result from an excess of mucus formation due to retained blood [16].

(4) Secondary infertility

Jolijn Vissers proposed a hypothetical mechanism for impaired fertility in the uterine niche [15].

- Hypothesis 1: Intrauterine fluid buildup associated with the niche affects implantation.

In approximately 42% of patients with a large uterine niche, fluid accumulation is observed. This may impact pregnancy outcomes by reducing implantation rates and potentially being toxic for embryos. Further research is needed to assess the impact of intracavitary accumulated fluid on implantation, the potential embryotoxicity of intrauterine fluid, and the efficacy of surgical procedures on reproductive outcomes. It remains unknown whether promptly removing intracavitary fluid before embryo transfer in women with niche influences reproductive outcomes [15].

- Hypothesis 2: Alteration of the immunobiological environment in the presence of a niche (inflammatory environment)

  A prospective cohort study of 380 women's early pregnancies after CS identified that the presence of a uterine niche influences the implantation site. The risk of spontaneous abortion was associated with the distance between the implantation site and the scar. Seven out of eight pregnancies with embryo implantation near or in the niche resulted in miscarriage. Implantation was more common in the posterior uterine region, suggesting that the niche is not an optimal site for implantation [17].

- Hypothesis 3: Distorted uterine contractility produced by fibrosis or myometrial disruption at the site of the niche

  Vissers proposes that irregular or uncoordinated uterine contractions following CS compromise implantation. In a normal menstrual cycle, steroids regulate coordinated contractions from the sub-endometrial myometrium. Optimal reproductive outcomes are associated with coordinated endometrial wave patterns. The study suggests that the lack of coordination or efficiency in uterine contractions in women with a uterine niche may disrupt typical wave patterns, potentially decreasing the rate of implantation [15].

- Hypothesis 4: The collected old blood and mucus in the niche and uterine cavity can hinder penetration of sperms

  We propose that a lower incision during CS across cervical tissue, containing mucus-secreting glands, may lead to the formation of mucus-filled niches due to local mucus production. TV/US and hysteroscopy reveal that many niches, particularly in low positions, are associated with Nabothian cysts. The accumulation of mucus and blood in these large niches and the uterine cavity may inhibit sperm penetration and embryo implantation. Spotting during coitus, with blood in the cervical canal, could hinder the interaction between cervical mucus and sperm for immunological reasons [15].

- Hypothesis 5: Physical obstacle/barrier to the embryo transfer and implantation

  A large uterine niche, often associated with a severely retroverted and fixed (RVF) uterus, can create challenges in accessing the uterine cavity for embryo transfer. This anatomical distortion poses difficulties during assisted reproductive technologies commonly used for infertility treatment. In some cases, the combination of a large uterine niche, a severely retroverted and fixed uterus, and a complicated niche may impede the insertion of a catheter for intrauterine insemination (IUI) or embryo transfer [15].

- Hypothesis 6: Psychological factors that lower the possibility of conception

  Symptoms of uterine niche, such as pain and spotting, can interfere with sexual activity. Medications prescribed for symptomatic relief may affect ovulation prospects during recovery. Sixty percent of women develop a uterine niche after CS, and 30% report postmenstrual spotting/bleeding. Unpredictable bleeding can occur at any menstrual cycle phase, causing anxiety, discomfort, and embarrassment, and impacting sexual behavior and arousal in affected women [15].

- Uterine niche effect on IVF/ICSI treatment

  Presence of uterine niche may have a detrimental effect on subsequent pregnancy of women undergoing IVF/ICSI treatment with lower pregnancy and livebirth rate [18]. This may be due to the following: difficult embryo transfer is encountered in 20% women with niche undergoing IVF, due to distorted anatomy, especially in a retroverted uterus (Kulshrestha, Agarwal, and Kachhawa 2020) [16]. Furthermore, decreased endometrial receptivity because of accumulated intrauterine fluid like hydrosalpinx or unfavorable microenvironment by changing endometrial microbiome or disrupted endometrial wave like activities needed for successful pregnancy [18].
  To date, no evidence supports niche repair to improve reproductive outcome in women undergoing IVF/ICSI treatment. Therefore, couples should be properly counselled about benefit/risks of niche repair prior to ICSI trial.

(5) Dysfunctional bladder

Despite the proximity between the uterine niche and the urinary bladder, it was hypothesized that locally accumulating fluid and fibrosis at the niche site might lead to dysfunction. However, prospective trials did not provide support for this hypothesis [16].

(6) Abscess at the site of scar

Abscess formation has been documented up to 6 years post-cesarean delivery, potentially due to infected remnants of blood and mucus, although this occurrence is uncommon [16].

Obstetric complications of uterine niche in future pregnancy

Isthmocele is associated with a higher risk of pregnancy-related complications, including CS scar pregnancy, abnormal placentation (previa- accreta—increta), and dehiscence at the scar site (partial or complete leading to ruptured uterus). The incidence of uterine rupture in posterior pregnancies is typically less than 2%, but it increases to 5% in the presence of large defects. Ultrasonography-measured scar thickness is not a reliable predictor of uterine rupture. Cesarean scar ectopic pregnancy, a rare obstetric issue where the embryo implants within the myometrium overlying the niche, has seen an increase in incidence in recent decades [2].

Uterine rupture or dehiscence risk in pregnancy with uterine niche according to RMT

Several studies have attempted to correlate RMT with the risk of uterine rupture during pregnancy. A cohort study had assessed 642 women with previous CS, reported a 4% rupture/dehiscence rate (15 ruptures, 10 dehiscence); moreover, the frequency increased as the myometrial thickness decreased. No cases of uterine rupture reported when RMT > 4.5 mm; on the other side, most cases of uterine rupture occurred when RMT was ≤ 2.5 mm. Cut-off > 3.5 mm of RMT, a sensitivity of 88.0%, a specificity of 73.2%, a positive predictivevalue of 11.8%, and a negative predictive value of 99.3% were used in estimating the risk of uterine rupture or dehiscence [19].

The emergent term CSDi

Trying to differentiate symptomatic niche from asymptomatic one: the term CSDi (caesarean section scar disorder) was emerged after Delphi study conducted 2023 by Klein Meuleman and his colleagues [20].

They defined CSDi as myometrial defect more than 2 mm with one primary symptom or two secondary symptoms. Primary symptoms or problems include postmenstrual spotting, pain related to uterine bleeding, secondary unexplained infertility with intracavitary retained fluid, and technical difficulties of catheter insertion during embryo transfer. Secondary symptoms include dyspareunia, chronic pelvic pain, abnormal vaginal discharge, avoiding sexual intercourse, negative self-image, abnormal odor related to AUB, unexplained secondary infertility, secondary infertility despite assisted reproduction, and discomfort during leisure activities participation [20].

Obstetric issues related to niche are defined as complications of CSDi, not primary or secondary symptoms. These complications include Cs scar ectopic, placenta accreta, uterine scar dehiscence, or rupture [20].

The following conditions should be excluded before diagnosis of CSDi: cervical dysplasia, vaginal or uterine infections, other intracavitary pathologies, anovulation, hormonal therapy, IUD [20].

The following criteria needed to apply CSDi: premenopausal women, cycle regular at least 3 consecutive cycles, onset of symptoms after CS or worsened after CS, patient can be cured from a symptomatic niche [20].

Figure 9 summarizes criteria of diagnosis of uterine niche.

Diagnosis

Ultrasonography, sono-hysterography, MRI, and HSG are imaging techniques commonly used to evaluate cesarean section scars and diagnose uterine niche in addition to hysteroscopy [2].

A) Imaging

(1) Ultrasound

Transvaginal ultrasonography (TV/US), being non-invasive and widely available, is the primary tool for assessing women with abnormal uterine bleeding (AUB) and a history of CS delivery. TV/US can detect uterine niche in 50% of cases, but its effectiveness depends on operator skill and hormonal influences [21]. Before the European Niche Taskforce's 2019 recommendations, there were no standardized criteria for assessing CS niche.

A landmark article by the Taskforce established a standardized method for identifying and assessing uterine niche using ultrasonography in non-pregnant women. Gel instillation sonography remains the standard method, but ultrasonography, performed during specific cycle days (7–14), may provide sufficient information without the need for gel instillation [21].

Table 3 summarizes the findings of a literature search that yielded articles that defined research questions related to ultrasonographic assessment of uterine niche (Appendix A).

- Ultrasonographic standard criteria for detection and diagnosis of the uterine niche (by European Niche Taskforce)

Sonographically, the uterine niche can be classified as simple, simple with one branch, or complex (main niche with more than one branch). A branch is a smaller part at the serosal side with a width less than that of the main niche (Fig. 1) [22]. For surgical planning, it is crucial to estimate distances between the niche and the external os, as well as between the niche and the vesicovaginal fold, although not essential for basic evaluation. Depth, width, length, residual myometrial thickness (RMT), anterior myometrial thickness (AMT), and distances to the vesicovaginal fold and external os are clinically significant measurements [23].

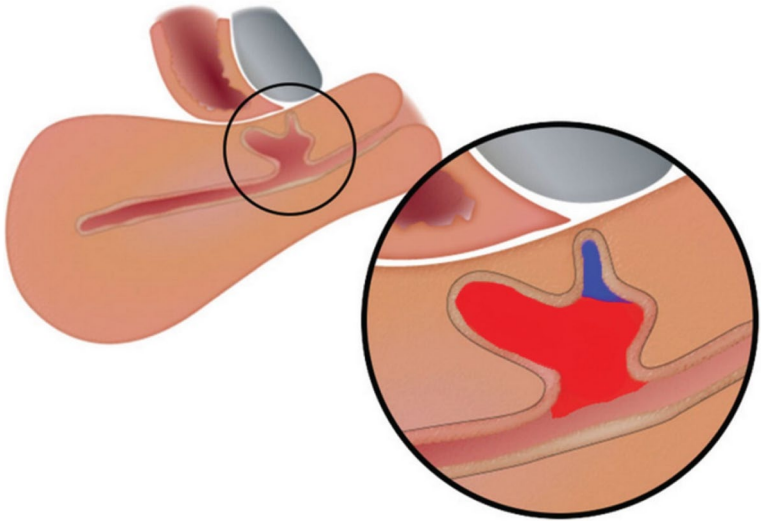


Fig. 1 Red area representing the main niche, while the blue-colored area represents the branch [22]

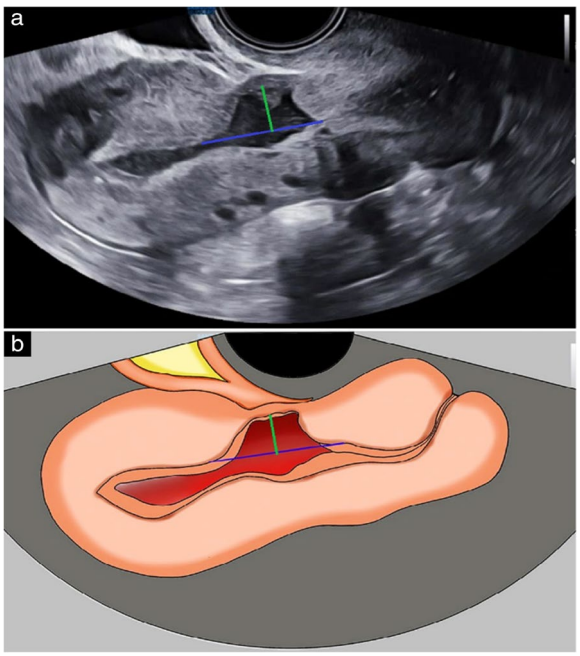


Fig. 2 Sagittal view of uterus measuring depth and length of uterine niche [22]

Measurements in the sagittal plane include length, depth, RMT, and AMT (Figs. 2 and 3) [22]. In the transverse plane, main niche width and branch identification are essential, without repeating RMT and depth measurements (Fig. 4) [22].

For a simple niche, measurements can be performed in a single plane, while complex niches may require multiple planes. Length and width measurements are preferred at the greatest width or length. Endometrium documentation is considered irrelevant to niche assessment; therefore, calipers should be placed on the myometrium boundary [23].

- Tips for the visualization of niches

Experts propose various recommendations and techniques to enhance niche visualization, emphasizing the importance of obtaining a clear view of the lower uterine section. In transvaginal ultrasound, the position of the probe (anterior vs. posterior fornix) and the pressure applied can significantly impact niche visualization. Greater pressure may be needed for more proximally positioned niches, while less pressure is required for those located distally or for assessing the vesicovaginal fold [1].

A full bladder is not necessary for visualizing the vesicovaginal fold. While Doppler ultrasound can be valuable for distinguishing a niche from other uterine wall abnormalities, it is not essential for niche assessment. The main key is to achieve a clear view of the lower uterine segment [1].

Table 4 summarizes the international guidelines for ultrasound evaluation of the niche [21, 24] (Appendix A).

- Role of 3D ultrasound in niche assessment

LUDWIN et al. introduced the VTS scoring method for categorizing uterine niches using 3D-SHG. A score of ≤ 2 suggests clinical irrelevance and further specific features should be assessed. A score > 2 indicates a clinically relevant uterine niche, necessitating close follow-up

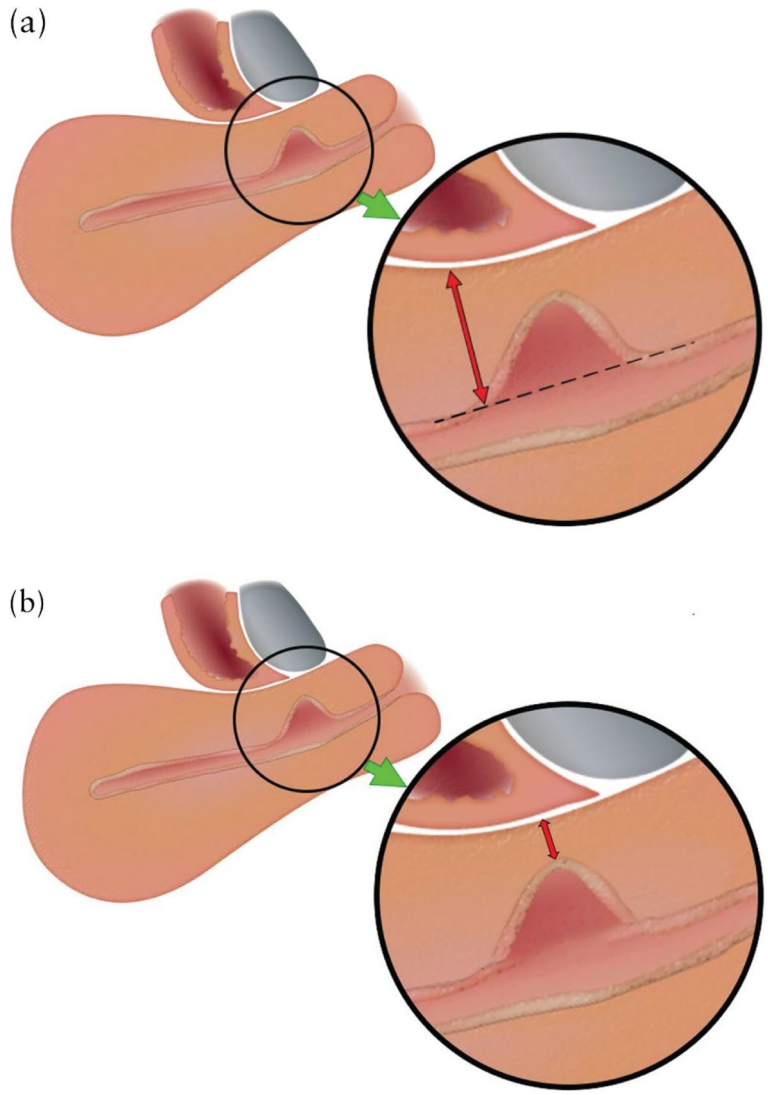


Fig. 3 Sagittal view of uterus to assess RMT and AMT [22]

in subsequent pregnancies. The volume can be calculated automatically, manually using VOCAL, or manually based on niche dimensions (depth × width × length × 0.52) [25] (Table 5, Appendix A).

(2) Other imaging

➢HSG

Hysterosalpingography (HSG) was among the initial modalities used to diagnose uterine niche (Fig. 5). A drawback of HSG is its inability to assess niche size and residual myometrial thickness, parameters easily determined by sono-hysterography [24].

➢ MRI

Wu Shun Felix Wong et al. explored the use of MRI in assessing cesarean scar defects (CSD). Notably, all sonographic parameters, such as depth, width, length, RMT, and AMT, can be measured using MRI as illustrated in Fig. 6 [26]. The limited documentation of CSD incidence by MRI suggests its underutilization as a diagnostic tool for patients with post-CS bleeding or infertility complaints mainly due to its cost. It may benefit in the presence of huge niches or suspicion of other pathology [26].

B) Role of endoscopy in the evaluation of niche

Hysteroscopy and laparoscopy provide direct visualization and identification of the Caesarean section scar niche. Hysteroscopic observations include indentation

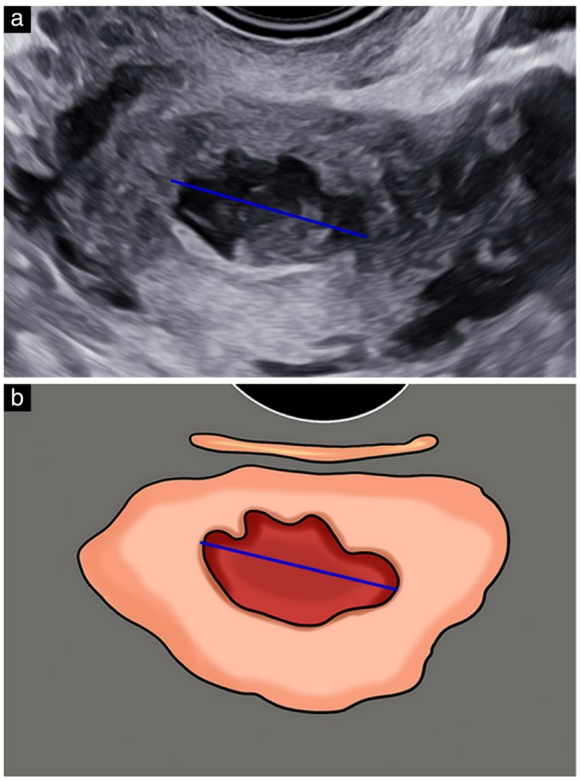


Fig. 4 Transverse plane of niche width [22]

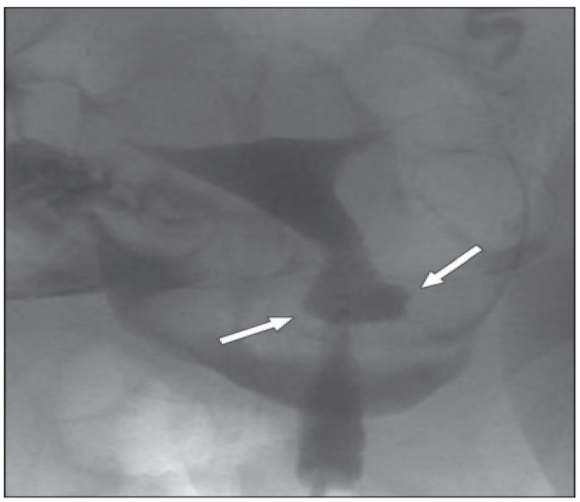


Fig. 5 Forty-year-old woman's hysterosalpingogram reveals a significant CS niche near isthmic part (arrows) [24]

or cavity within the isthmic myometrium, a prominent distal ridge, breach of the lining mucosal layer, presence of lateral branches, aberrant vascular patterns at the base, and cyst-like or polypoid formations [21].

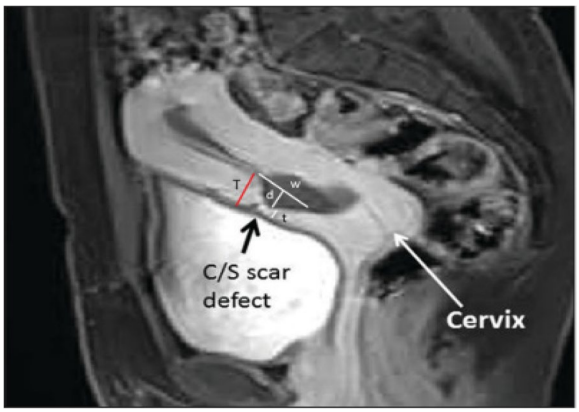


Fig. 6 Cesarean scar Niche measured by magnetic resonance imaging: D stands for the defect's depth, w for its width, t for the scar myometrium's thickness, and T for the adjacent myometrial thickness [26]

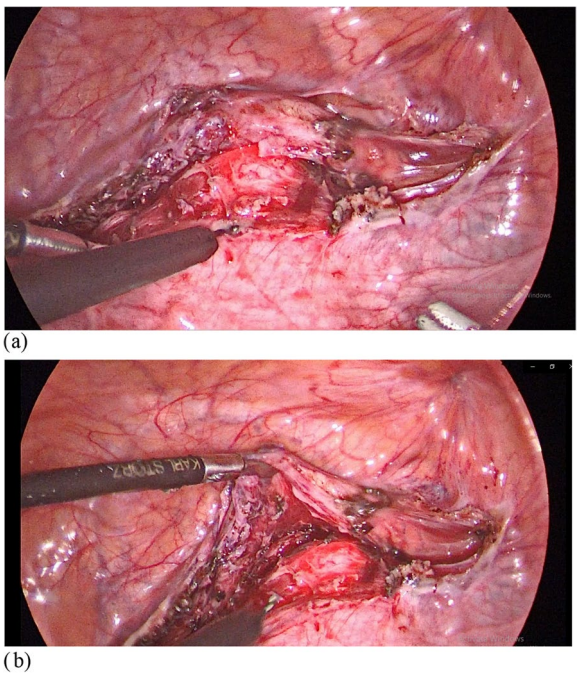
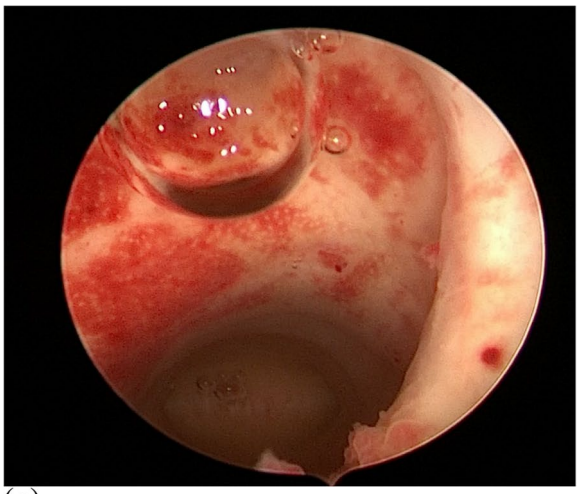
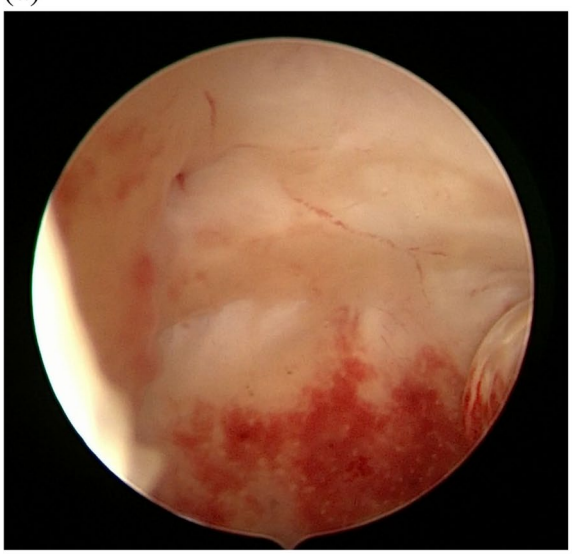


Fig. 7 Laparoscopic view of uterine niche after bladder dissection, concomitant hystroscopic transillumination

Hysteroscopy allows both visualization and treatment of the niche but cannot assess residual myometrial thickness [2]. In laparoscopy, the niche may manifest as ballooning of the lower segment, often accompanied by adhesions to the bladder or anterior abdominal wall. Recognizing these patterns is crucial for accurate documentation in women undergoing gynecological examinations [21]. See laparoscopic (Fig. 7a,b) and hysteroscopic (Fig. 8a,b) images for illustration.



(a)



(b)

Fig. 8 **a**, **b** illustrate hysteroscopic view of uterine niche 34 years, precious 2 CS, complaining of postmenstrual spotting, chronic pelvic pain

Management of uterine niche

The decision to treat uterine niche depends on factors like symptoms, secondary infertility, pregnancy plans, and defect size. For asymptomatic cases with no pregnancy plans, conservative management through clinical observation is often recommended. Management options include:

(1) Clinical management

- *Expectant management:* Monitoring without intervention.
- *Pharmacological treatment:* Medications for symptom relief.

(2) Surgical management

- *Reconstructive surgery:* Utilizing various methods such as hysteroscopy, laparoscopy, transvaginal repair, laparotomy, or combined approaches.
  - Hysteroscopic approach
  - Laparoscopic approach
  - Vaginal approach
  - Laparotomy
- *Radical surgery:* Hysterectomy [2]

Reconstructive surgery is commonly preferred, but each approach carries specific risks like infections, bowel/bladder injury, and hemorrhage. The choice of treatment depends on individual circumstances and preferences [27].

(A) Medical management

Oral contraceptives show efficacy in reducing bleeding issues associated with isthmocele. A study demonstrated that a three-cycle course of combined oral contraceptives (COCs) led to a reduction and cessation of spotting, Florio et al. compared hormonal therapy with hysteroscopic repair for alleviating uterine niche symptoms, revealing that hysteroscopic correction was more successful in reducing the duration of postmenstrual spotting and pelvic pain [27].

Various management options, including laparoscopic and vaginal repair, hysteroscopic ablation, COCs, and levonorgestrel intrauterine system, were evaluated, indicating effectiveness in shortening the menstrual cycle in symptomatic patients, except for levonorgestrel intrauterine system [28]. However, cyclic oral COCs had inferior results compared to hysteroscopic niche resection according to a systematic review by Vander voet et al. [29].

(B) Surgical management

Indications for niche surgery include persistent menstrual disturbances (postmenstrual and intermenstrual spotting) and infertility attributed to the uterine niche. Surgical options encompass radical measures like hysterectomy and reconstructive techniques employing minimally invasive approaches. Commonly discussed in the literature are laparoscopic niche repair (with or without hysteroscopic guidance), hysteroscopic approaches,

transvaginal niche repair, and combinations of these techniques [21].

(1) Hystroscopic approach

Hysteroscopic repair of uterine niche is a minimally invasive and low-risk procedure involving diagnostic and operative hysteroscopy, known as isthmoplasty [2]. The procedure is focused on addressing RMT, a critical consideration [27].

The literature emphasizes RMT as the primary factor for choosing hysteroscopic repair. Potential risks include bladder injury and uterine perforation, especially when RMT over the niche is ≤ 3 mm. Some authors recommend hysteroscopy for women with RMT greater than 2 to 2.5 mm or a niche depth to myometrial thickness ratio of less than 50%, even if not desiring future pregnancy, but caution is needed due to the risk of bladder injury and perforation [27].

Isthmoplasty methods vary, with common approaches involving resection of proximal and distal niche edges using a 9-mm resectoscope and unipolar electrical current. Electrocauterization of the niche base is commonly performed. Other techniques include shaving the niche edges, connecting it to the cervical canal [30], or removing fibrous tissue beneath the niche [31]. Sonographic guidance may be used but does not necessarily reduce morbidity [32].

A 2015 multicenter randomized controlled trial in the Netherlands showed significant improvement in the postmenstrual bleeding duration and associated pain after hysteroscopic isthmoplasty in patients with at least 3-mm RMT uterine niche [33].

Bladder injury risk makes hysteroscopic resection unsuitable for women with RMT ≤ 3 mm, recommending laparoscopic or vaginal procedures. Resection of the caudal ridge poses a theoretical risk of cervical incompetence, leading some authors to discourage it [21].

Table 6 illustrates the studies that evaluated the effect of hysteroscopic repair of uterine niche (Appendix A).

(2) Transvaginal approach

The transvaginal approach for repairing uterine niche is a minimally invasive and effective method [2]. The procedure, as described by Chen et al., involves placing patients in the dorsal lithotomy position, evacuating the bladder with a catheter, and using vaginal retractors to expose the cervix. Adrenaline is administered for hydro dissection and hemostasis. An incision is made at the cervicovaginal junction, and dissection proceeds until the peritoneum of the vesico-uterine pouch is identified. The retractor is positioned to provide a clear view, and a transverse incision is made at the identified niche level. The uterine defect is then repaired by removing the niche and suturing the incision edges [34]. This transvaginal approach is comparable to laparoscopic repair in efficacy but offers shorter surgical time and lower hospital costs [27].

Table 7 summarizes the studies that evaluated the effect of vaginal repair on uterine niche (Appendix A).

(3) Laparoscopic approach

The laparoscopic approach for repairing large uterine niche defects (RMT ≥ 3 mm) in symptomatic women with a desire for future pregnancy involves excising niche edges to remove scar tissue and closing the defect with two-layer sutures [2]. Introduced in 2003 by Jacobson, this approach has been adopted by various authors. It requires a trained laparoscopic surgeon proficient in conventional laparoscopy or robotic surgery [27].

Identifying the niche correctly is crucial and can be achieved through various techniques

- Hysteroscopic transillumination: Concurrent hysteroscopy during laparoscopy enhances niche identification as the hysteroscope light is more evident at the thinner endometrium of the niche.
- Concurrent TV/US: Transvaginal sonography can be employed if the scar is not directly discernible following uterovesical space dissection.
- Foley catheter at LUS: Inserting a Foley catheter through the cervical canal into the uterine cavity and filling it at the lower part helps identify the niche.
- Slip and hook technique: If direct identification is challenging, a Hegar dilator is slid forward blindly against the anterior uterine wall at the isthmus, creating a "hooking effect" for niche perforation with laparoscopic guidance.

Table 8 detects the studies that evaluated the effect of Laparoscopic repair of uterine niche (Appendix A).

(4) Laparotomy

Laparotomy offers complete excision of dehiscent myometrium and precise uterine repair [27].

In a systematic review by van der Voet (2014), comparing hysteroscopic isthmoplasty (87%) to laparoscopic repair (100%), both showed a significant reduction in postmenstrual and intermenstrual spotting and pain [29]. However, many included papers had poor to intermediate methodological quality [21].

Vitale et al. conducted another systematic review and meta-analysis, analyzing approximately 33 papers.

Hysteroscopic resection improved symptoms in 85.00%, laparoscopic repair (including robotics) in 92.77%, and vaginal repair in 82.52% of women. Hysteroscopic surgery had the lowest complication risk (0.76%) [35].

There is sufficient evidence to justify surgical intervention for symptomatic niche management, with intervention reported to reduce bleeding symptoms in over 80% of patients. However, evidence supporting surgery to improve reproductive outcomes or reduce obstetric complications in subsequent pregnancies is not as established [35].

Laparoscopic and transvaginal approaches are preferred for patients with a thin remaining myometrium above the niche (≤2.5 mm) when the hysteroscopic approach fails. Hysteroscopic isthmoplasty may be the safest and most effective in patients with sufficient RMT above the niche, while laparoscopic and transvaginal surgeries are preferable for women with a thinner RMT above the niche (≤2.5 mm) [35].

Table 9 summarizes the studies that evaluated the effect of different approaches for the repair of uterine niche (Appendix A).

Reproductive outcome after niche management

In a systematic review by Harjee, comprising 13 studies (1 RCT, 6 prospective case series, and 6 retrospective case series) on 234 patients with uterine niche and secondary infertility, surgical intervention was performed in 188 patients via hysteroscopy, 36 via laparoscopy, 7 via

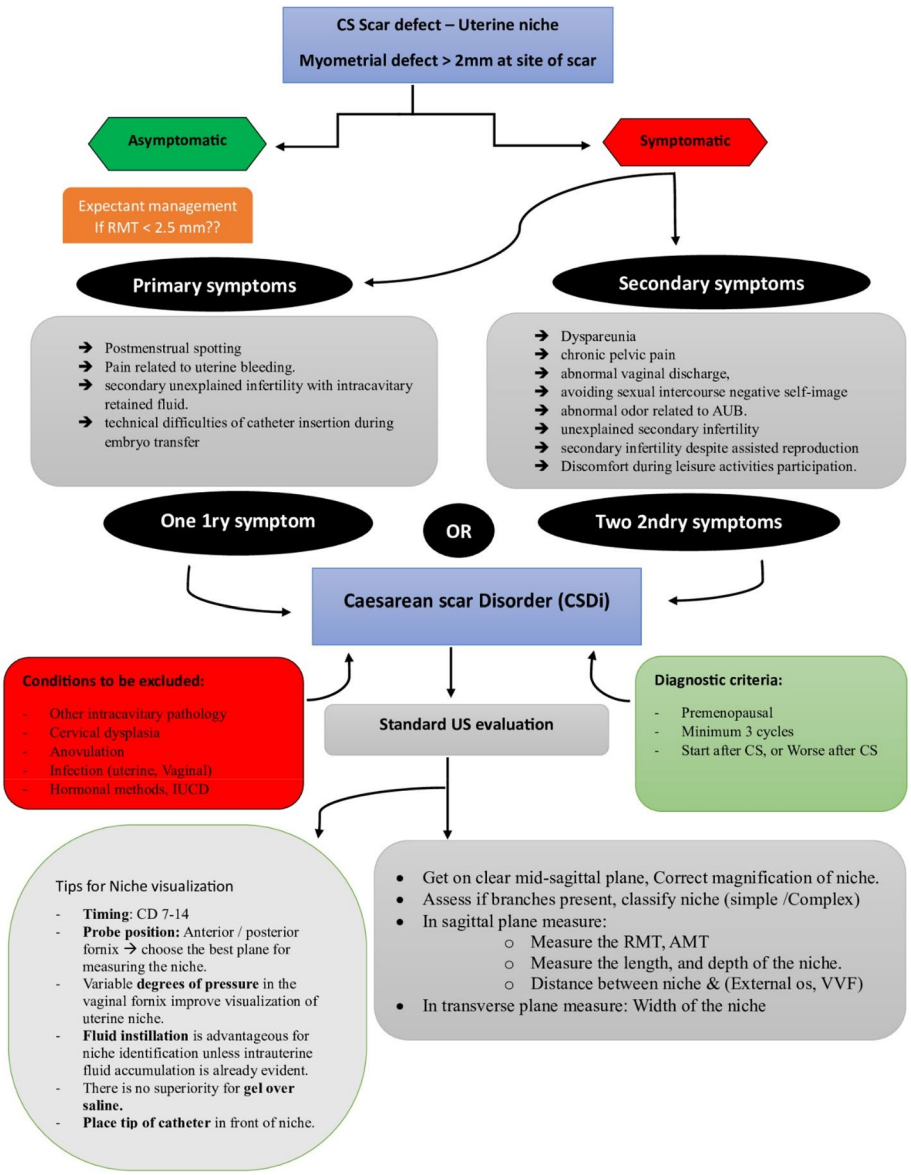


Fig. 9 Diagnostic criteria of uterine niche and CSDi

laparotomy, and 3 vaginally. Overall, 65.4% of patients became pregnant, with a live birth rate of 87.1%. The reoperation risk was 2%. Hysteroscopy showed better pregnancy outcomes compared to untreated cases in the RCT [36].

Verberkt et al.'s systematic review included 21 papers (1 RCT, 1 case series, 5 prospective, and 14 retrospective cohort studies) with 648 women experiencing secondary infertility and 237 without infertility. The live birth rates were higher in infertile women (54%) than those without infertility (36%). Different surgical approaches (hysteroscopic, laparoscopic, and transvaginal repair) showed varying live birth rates in infertile women, with hysteroscopic isthmoplasty demonstrating better outcomes 55%, 60% after vaginal repair, and 42% after laparoscopic repair. Versus 52%, 25%, and 36% respectively in women without infertility the pregnancy rate following hysteroscopic isthmoplasty was significantly higher than with expectant care (RR 2.41), as reported in the single RCT. Scar dehiscence was documented in 2.8% of deliveries following hysteroscopic repair, while laparoscopic and transvaginal approaches did not show scar dehiscence. The overall quality of the analyzed trials ranged from moderate to poor, with a notable risk of bias. Many included studies did not evaluate or document evaluation of other factors of infertility including semen analysis, tubal pathology, endometriosis [37].

Table 10 summarizes the studies reporting the pregnancy rate after management of uterine niche for women complaining of infertility (Appendix A).

Conclusion

In conclusion, pathogenesis of niche formation is still unclear with different hypotheses. Ultrasound assessment of RMT is essential to determine surgical repair approach. Repair of uterine niche will improve symptoms (bleeding, pain), with no evidence to improve reproductive outcomes/obstetric complications in following pregnancies.

Figures 9 and 10 summarize algorithms for diagnosis and management of uterine niche.

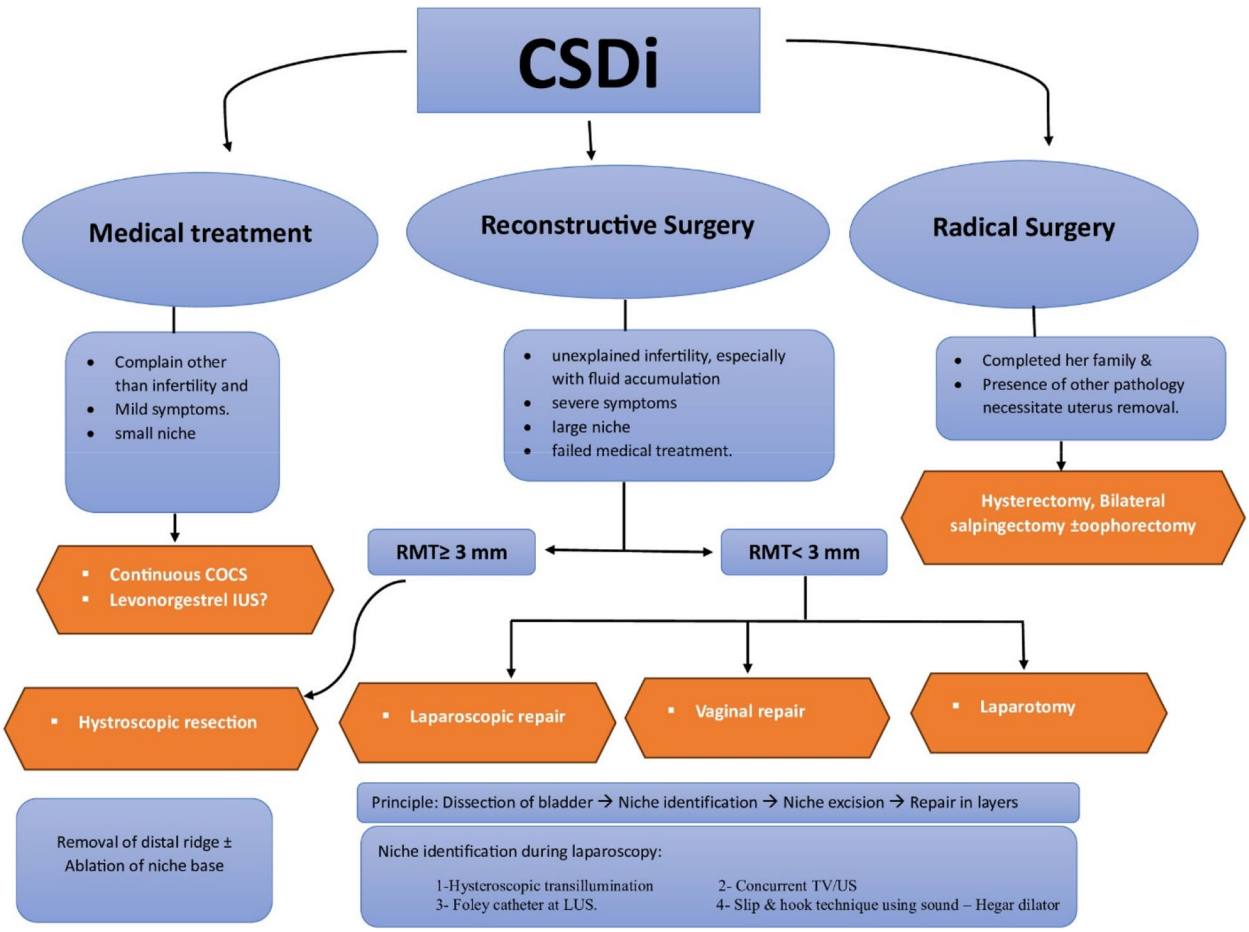


Fig. 10 Summarize algorithms for management of symptomatic uterine niche / CSDi

Appendix A

Table 1 Studies evaluating the relationship between CS type and uterine niche formation

	Author	Study design	Sample size	Comparator	Outcome	Results
1	Vikhareva Osser [38]	Observational cross-sectional study	108	Effect of different circumstances around primary CS on Niche formation TV/US 6–9 m	Factors that increase the risk of huge niche formation	• Incidence of huge niche 20% The odd of a huge niche is more with • Advanced dilatation of cervix at time of CS ($P<0.001$) • Advanced descent presenting part (fetal station during CS) (OR 14.1 – P value less than 0.001), • Labor duration before CS ($P<0.001$) • Oxytocin augmentation ($P<0.001$)
2	Hanacek [39]	RCT	324	-Elective CS -Emergent CS	TV/US 3 intervals (6 weeks, 6–12 months postpartum) RMT, level of niche	CS during full cervical dilation • RMT thinner ($P=0.01$) • Level of niche more distal (0.0000) • Less defect width defect smaller (0.001)
3	Zimmer [11]	Cross-sectional study	353	-CS before cervical dilatation (180) -CS after cervical dilatation (173)	TV/US to determine niche prevalence, distance from os	with CS done in the active phase of Labor • Prevalence of niche more ($P<0.0001$) • Level of niche more distally located ($P=0.01$)

Table 2 Studies evaluating the relationship between cesarean section closure technique and niche formation

	Author	Study design	Sample size	Active comparator	Main outcome and duration	Results
1	Yazicioglu [40]	RCT	78 secondary & elective CS	• Full-thickness repair • Split-thickness repair	Incidence of niche (C) ays after delivery)	• 44.7% full thickness • 68.8% split thickness
2	Hayakawa [41]	Prospective cohort	137	• Single-layer interrupted repair (50) • Double-layer interrupted repair (51) • Continuous suture without decidual sparing then interrupted suture of the myometrium (36)	Incidence of niche after 1 m	• 34% single layer • 16% double interrupted layer • 5.6% continuous 1st layer, interrupted 2nd layer
3	Yasmin, Sadaf [42]	RCT	60	• Single layer locking (26) • Double layer 1st locking (28)	• RMT 6 weeks postpartum • examination of uterine scar during the next CS delivery	• RMT one layer locked (13.19 + 1.32 mm) • RMT two-layer closure 1st locked (14.58 + 1.18 mm). • Uterine dehiscence at the next CS 23% in single, 14% in double
4	Ceci [43]	RCT	60	• Locked continuous single layer. • Single-layer interrupted sutures.	Incidence, size of niche Between 6 and 12 m, at 24 m	• Larger niche with continuous repair (6.2 (2.1–14.7) mm^2) • Interrupted sutures (4.6 (1.9–8.2) mm^2)

	Author	Study design	Sample size	Active comparator	Main outcome and duration	Results
5	Sevket [44]	RCT	36	• Single locked layer • Double layer (locked/unlocked)	RMT, healing ratio of niche after 6 m by sonohystrography	Mean RMT covering the niche was greater following double-layer. • Double layer (9.95 ± 1.94) mm • Single layer (7.53 ± 2.54) *P* value = 0.005 Healing ratios mean with double layer significantly better than with single layer closure (*P* = 0.004)
6	Roberge [45]	3 arm RCT	81 Primary-elective CS at gestational age ≥ 38	• Single layer locked sutures without decidual sparing (27) • Double layer (with locking the first layer) without decidual sparing (27) • Double layer (without locking the first layer) with decidual sparing (27)	RMT by TV/US 6 months after CS	• Repair of uterine incision by double layer without locking the first layer has increased RMT in comparison with single layer (3.8 ± 1.6 mm VS 6.1 ± 2.2 mm; *P* < 0.001) and higher healing ratio (*P* = 0.004) repair. • No significant differences between uterine repair by single / double layer (locked first layer) repair in terms of RMT; *P* = .032 or healing ratio *P* = .287
7	Kataoka [46]	Prospective cohort study	384 Primary cesarean section	• Single layer (58) • Double layer (209)	RMT, Niche depth, ratio 3–4 months postpartum by Sonohysterography	• > Fivefold increased odds of a niche (OR ≥ 0.4) were related to single-layer repair. (odds ratio 5.59 at 95% CI) • Niches in single-layer 24.1% (14) • double-layer 26.3% (55) (*p* = 0.74)
8	Bamberg [47]	RCT	435	• Single nonlocked layer repair (149) • Single locked layer repair (157) • Double layer repair (129)	Incidence of niche by transvaginal ultrasonography follow-up was done after CS at (6 w – 6 m – 24 m) interval	• Six weeks after delivery, niche incidence was similar between groups (*p*-value 0.52). (40%, 32%, 43%) • At 6 m insignificant statistical difference in the incidence of niche (*p* = 0.58). (30%, 23%, 29%) • Long-term residual myometrium thickness was thicker following double-layer repair (*p* = 0.06)
9	Tekiner [48]	Prospective cross-sectional study	280	• Single layer (126) • Double layer (156)	Detect uterine niche depth and length 3 months postpartum by sonohystrography	• Statistically the depth and length of the niche did not differ significantly between the two groups (*p* = 0.70)
10	Hanacek [39]	RCT Elective or acute cesarean section	324	• Single layer (149) • Double layer (175)	Niche incidence, size, RMT by TV/US at three consecutive visits(6 weeks – 6 months – 12 months postpartum)	• Incidence of niche higher in a single layer, Wider (0.002) • RMT is thinner in the single-layer group (0.019).
11	Yılmaz Baran [49]	RCT	282 primary	• Single layer locked (109) • Double layer (1st locked) (116) Decidual sparing in both	Incidence of niche within 6–9 months postpartum	The statistically insignificant difference regarding Niche incidence • Single layer 37% • Double layer 45.7% *P* = 0.22

	Author	Study design	Sample size	Active comparator	Main outcome and duration	Results
12	Stegwee [50]	RCT	2292 Primary CS	• Single layer unlocked • Double layer unlocked	Days of PMS Incidence of niche	PMS • No significant difference in duration between 2 techniques ($P=0.810$) Niche incidence • More with double layer ($P=0.022$)
13	Roberge [51]	Systematic review 20 RCT	13,086 participants	• Single CS double-layer	Niche formation, RMT within 6 m	• Insignificant difference regarding the incidence of Niche with single layer Versus double layer repair $p=0.12$ • As regards RMT: lower RMT with single layer VS double layer repair ($p<0.001$)
14	Di Spiezio Sardo [52]	Systematic review 9 RCT	3969 participants	• Single-layer vs double-layer	Incidence of niche	• Uterine repair by single layer had no statistically significant difference in the rate of Niche Vs uterine repair by double layer. (25% vs 43%) RR 0.77 at 95% CI
15	Stegwee [53]	Systematic review 20 Trials (RCT, Prospective cohort)	15,053 participants	• Single vs double-layer • Locked Vs non-locked • Decidual inclusion /not	RMT, healing ratio Niche prevalence	RMT Reported in 8 trials (508) • Single Vs double layer repair decreases by a mean of 1.26 $p=0.0003$ • Thinner RMT with locked sutures Healing ratio • Is less with single compared with double layer repair by mean 7.74% $p=0.006$ • Less a healing ratio with locked sutures Niche incidence • Significantly more with decidual sparing ($p=0.02$)
16	Qayum [54]	Systematic review 18 RCT	16,303 participants	Single-layer versus double-layer	RMT, Healing ratio Within 6 m	RMT • Significant less with single layer vs double layer (P value $<.0001$) Healing ratio • Insignificant difference between single-layer repair and double-layer ($p=0.18$)
17	Marchand [55]	Systematic review 20 RCT	8799 participants	Single-layer versus double-layer	RMT, Niche Incidence 6 w, 6–26 m follow-up	RMT • Significantly thicker with double layer repair at 6 w, 6–24 m ($P=0.01$) Incidence of niche • No significant difference at 6 w or 6–24 m between single and double layer ($P=0.93$, $P=0.18$)

Table 3 Two- and three-dimensional ultrasonography with or without SIS for the diagnosis of uterine niche

	Study author	Study design	Research question	Results
1	Woźniak [56]		Optimal timing for niche measurement	Immediate after the end of menstruation, when the endometrium is the thinnest, is the most optimal time for a US assessment.
2	Allison [57]		Effective method for measurement (TVS or contrast)	Saline infusion is a valuable complement to Transvaginal sonography, particularly for endometrial and adjacent lesion assessment.
3	Baranov [58]	Cohort study		Niche detected in 46.4% of cases by TVS, VS 69.1% of cases on saline contrast,
4	Vikhareva Osser [10]	Cohort study		• The shape of the niche did not alter at saline sonohystrography; however, it is simpler to distinguish the scar defects' borders at sonohystrography than at non-contrast ultrasonography. • The depth and length of the niche at saline sonohystrography were more than they were previously. The difference was 2 mm and 1 mm in women with the previous 1 CS, while the difference was 4 mm and 2 mm in women with the previous 2 CSs.
5	Tower [59]	Overview of literature		Saline infusion sonography provides more sensitivity and specificity than TVS for detecting uterine niche. If niche is suspected, assessment with saline infusion sonography is recommended, except if the procedure is undesirable or contraindicated, trans-vaginal US may be done
6	Bij De Vaate [8]	Observational prospective cohort study		• Niche prevalence with transvaginal sonography: 24% • Niche prevalence with gel instillation sonography: 56%
7	Van Der Voet [9]	Prospective cohort study		• Niche prevalence using TVS:49.6%, • The prevalence with gel infusion was 64.4%.
8	Antila-Långsjö [60]	Prospective cohort study		TV/US and SHG do not agree well in the diagnosis of niche, and TV/US use alone probably results in an underestimating niche prevalence. Therefore, SHG should be considered the diagnostic technique of choice for a niche
9	Marjolein Bij De Vaate [61]	Prospective cohort study	Best method (3D- or 2D-TVS) to use for assessment of size	In the sagittal plane, 3D is a reliable method for measuring uterine niche dimensions & residual myometrial thickness.
10	Giral [62]	Retrospective study		Niche prevalence by 3D-TVS is 50%, but by 2D saline infusion sonography, it is 86%. Sonohysterography with saline contrast is more sensitive than 3D transvaginal ultrasonography for assessing cesarean scar defects. Moreover, it examines the size and shape of the defect more precisely, hence estimating its severity.

	Study author	Study design	Research question	Results
11	Alalfy [63]	Observational cross-sectional comparative study		3D ultrasonography with SHG is superior to 2D SHG in evaluating the niche width and RMT before ICSI, hence offering a more accurate assessment of the scar niche.
12	Naji [64]		Niche specified measures	RMT—depth, length and width of niche must be assessed sagittal and transverse planes.
13	Tower [59]			RMT measured from the defect's apex to the myometrium's edge.
14	Fabres [65]	Retrospective study	The ideal time of the menstrual cycle to assess uterine niche.	Sonography is most effective for identifying uterine niche during the bleeding phase, typically a few days following menses.

Table 4 International guidelines for the ultrasonographic evaluation of uterine niche

		Proposed TV/US standard	Recommendation of consensus
1	Definition of niche		• Niche depth ≥ 2 mm • Ignore the endometrium • Obtain clear view of lower uterine segment
2	How to assess niche systematically?	How to obtain sonographic planes: • Get on clear mid-sagittal plane (the start) • Rotate to transverse plane • identification of branches	• Locate the cervical canal by sweeping laterally in both directions on sagittal planes. • Rotate the probe 90° from the sagittal to the transverse plane. • To evaluate the niche and identify branches, sweep from the cervix to the corpus.
		Specific niche measurements: length, width, and depth	• In sagittal plane measure: ○ Measure the RMT ○ Measure the length, and depth of the niche. • In transverse plane measure: ○ Width of the niche
		• RMT: • related fibrosis • Accessory branch of main niches	• Measure just the thinnest RMT • Rule out related fibrosis • For the accessory branch: Measure the RMT and width
		AMT	• Measure the thickest part of the |myometrium close to the niche
		Associated structures	Two distances are important to measure: ➢ 1st between uterine niche and the vesicovaginal fold ➢ 2nd between uterine niche and the external os
3	Visualization tips	Correct magnification of niche	Allows accurate niche measurement and niche relationship
		Visualization in the sagittal and transverse planes	• Correct orientation depending on specific niche characteristics. • Take measures to modify probe orientation to enable optimal lower-segment visualization
		Transvaginal probe positioning	Where to put the vaginal ultrasound probe at the anterior fornix or posterior fornix influences obtaining the best plane for measuring the niche.

		Proposed TV/US standard	Recommendation of consensus
4	Adjunctive methods	transvaginal probe pressure	Variable degrees of pressure in the vaginal fornix improve visualization of uterine niche
		Doppler ultrasonography	Not required but can help differentiate other structures
5	Contrast sonography	Use of contrast-sono-hysterography by saline /gel	• Fluid instillation is advantageous for niche identification unless intrauterine fluid accumulation is already evident. • There is no superiority for gel over saline.
		Catheterization insertion and tip position	• No certain type of catheter is superior. • You should place catheter tip in front of the niche or just above most proximal portion, then slowly retracted towards the niche's base.

Table 5 Correlation between imaging criteria and clinical significance of uterine niche

Feature	Score		
	0	1	2
Volume ¥	< 0.1 cm^3	0.1–1.0 cm^3	> 1.0 cm^3
RMT	> 3 mm	1–3 mm	< 1 mm
Supplementary features	Absent	Present	
✓ Branches, niche not covered by Urinary bladder and suspicion of deep infiltrating endometriosis in niche.			—

Table 6 Studies evaluated the effect of hysteroscopic repair of uterine niche

No	Author	Study design	Sample size	Results	Complications
1	Chang [66]	Prospective study	22	Improvement of postmenstrual spotting in 64% of patients (14). 36%patients (8) still have PMS for 6.38 ± 1.3 days.	Not available
2	Fabres [67]	Retrospective study	24	• 20 (84%) of patients improved • Between 14 and 24 months of follow-up, 81.8% (9/11) of infertile patients became pregnant.	No complications
3	Feng [68]	Retrospective study	62	Postmenstrual spotting was improved in 93.5% of patients (58)	No complications
4	Florio [69]	Retrospective study	19	Hormonal treatment (4.9 days) was inferior to hysteroscopic ablation (2.4 days) regarding PMS.	No complications
5	Gubbini, Casadio [30]	Prospective study	26	All patients were clinically improved. 7 out of 9 (77.8%) infertile women became pregnant.	Not available
6	Gubbini [70]	Prospective study	41	• Clinical improvement in all patients 100% of patients • Between 12 and 24 months after surgery all infertile patients (100%) got pregnant spontaneously	Not available
7	Pérez-Medina [71]	Retrospective study	22	• Clinical improvement of all patients • 66.6% of infertile patients achieved pregnancy (10 of 15)	No complications
8	Raimondo [72]	Prospective study	120	• Clinical disappearance of symptoms in 96 (80%) of patients • 8 (7%) decrease symptoms severity • 16 (13%) no change in symptoms	No complications
9	Vervoort [73]	RCT	52	The median duration of PMS was 4 days compared to 7 days in the expectant management group	1 PID (1.9%)

No	Author	Study design	Sample size	Results	Complications
10	Wang [74]	Retrospective study	57	• The association between a retroflexed position of the uterus and treatment failure was shown to be statistically significant. • 34 patients (59.6%) showed an improvement in PMS.	No complications

Table 7 Studies evaluated the effect of vaginal repair on uterine niche

No	Author	Study design	Sample size	Results	Complications
1	Chen [75]	Retrospective	241	(51.9%) of patients improved with duration of menstruation ≤ 7 days	3 hematomas 2 cystotomies
2	Chen [34]	Retrospective	64	85.9% of patients experience postoperative clinical improvement.	No complications
3	Luo [76]	Retrospective	42	• 92.9% of patients experience postoperative clinical improvement. • (7%) of patients still have postmenstrual spotting	1 (2.4%) postoperative infection
4	Zhou [77]	Retrospective	121	• (80.3%) of patients achieved menstrual days ≤ 10 days. • Loss of follow-up (4) patients	3 hematoma
5	Zhou [78]	Prospective	143	• Niche disappeared after surgery in (80/124) of patients (64.52%) • 62/124 of women (50%) have duration of menstruation ≤ 7 days	2 hematoma
6	Klemm [79]	Retrospective	5	• 4 patients became asymptomatic • 1 patient got pregnant • loss to follow in 1 patient	No complications

Table 8 Studies evaluated the effect of laparoscopic repair of uterine niche

No	Author	Study design	Sample size	Results	Complications
1	Donnez [80]	Prospective study	3	• Resolution of pelvic pain and dysmenorrhea in all patients. • One of the patients got pregnant	No complications
2	Donnez [81]	Prospective study	38	• 30/33 (90.9%) clinical improvement • 8/18 (44.4%) infertile women got pregnant	No complications
3	Liu [82]	Retrospective study	49	• Symptoms were relieved in 44/49 (89.8%)	No complications
4	Marotta [83]	Prospective study	13	• Whole patients show Clinical improvement (100%) • 4/13 patients got pregnant spontaneously	No complications
5	Nirgianakis [84]	Retrospective study	21	• Clinical improvement in 95% (20/21) • Just documented 1 case of recurrent CSD 6 w after intervention	No complications
6	Urman [85]	Case report	1	• The patient reported Clinical improvement. • Minimal residual defect (0.5 cm)	No complications

No	Author	Study design	Sample size	Results	Complications
7	Vervoort [86]	Prospective study	101	• Clinical efficacy reported in 79.2% (80/101) • No report on post operative US	5 Cases Conversion to a laparotomy for entry related vascular injury, inferior epigastric injury, 2 bladder injury. 1 uterine perforation by hysteroscopy
8	Hofmans [87]	Retrospective study	13	• 69.2% reported clinical improvement. • No report on postoperative US	1 case of bladder injury
9	Nezhat [88]	Retrospective study	27	• 78% reported clinical improvement. • No postoperative US follow up	Not reported

Table 9 Studies that evaluated the effect of different approaches for repair of uterine niche

No	Author	Study design	Intervention	Sample size	Results	Complications
1	Li [89]	Retrospective	Hystroscopic Laparoscopic	34 17	• 16/17 patients treated with laparoscopy and 20/24 patients treated with hysteroscopy experienced clearance of PMS. • Two-thirds of infertile patients who underwent laparoscopic treatment conceived.	Not available
2	Tanimura [90]	Prospective	Hysteroscopic Laparoscopic	4 18	• All patients were diagnosed with secondary infertility. • 100% of patients in the hysteroscopy approach and 55.6% of patients in the laparoscopy approach achieved pregnancy.	No complications
3	Zhang [28]	Prospective	Hystroscopic Laparoscopic Vaginal	19 86 14	• After surgery, all patients reported shorter menstrual periods. • Thirty-two patients who desired to conceive underwent laparoscopy. 37.5% of them (12) got pregnant	No complications
4	Xie [31]	Retrospective	Hystroscopic Vaginal	31 46	• The outcomes of vaginal versus hysteroscopic treatment were superior (93.5 versus 64.5%), • Despite the operation time being longer (55 versus 25 min) and more loss of blood (50 versus 10 ml). • Patients in both groups experienced an improvement in menstrual duration.	No complications 1 postoperative infection (2.2%)
	Zhang [91]	Retrospective	Laparoscopic Hystroscopic	13 33	• No significant difference in clinical improvement • Hystroscopic repair has shorter operative time, hospital stay, less blood loss and hospital expense.	1 bladder injury Not reported

Table 10 Studies reporting the pregnancy rate after management of uterine niche for women complaining of infertility

No	Author	Study design	No. of infertile patients (Cause)	Approach	No pregnant postoperative	Time of follow-up	Reported outcome of pregnancy
	Hysteroscopic approach						
1	Fabres [67]	Retrospective study	11 (9 unexplained,1 male, 1 tubal factor)	Hysteroscopic	9	14–24 m	Not reported
2	Gubbini [70]	Prospective cohort study	41 (unexplained)	Hysteroscopic	41	14–24 m	37 ➔ CS delivery 4➔ miscarriage
3	Abdou [92]	RCT	56 (Unexplained)	28 ➔ hysteroscopic (A) and expectant (B)	(A) 21 (B) 9		Hysteroscopy group 4 ➔ miscarriage 17 ➔ cs
4	Calzolari [93]	Retrospective	16 (unexplained)	Hysteroscopic	9	12 m	NR
5	De Albornoz [94]	Prospective case series	11 (Not reported)	Hysteroscopic	3 of 7 completed follow-up	12 m	1 ➔ miscarriage 2 ➔ CS
6	Dou [95]	retrospective	99 (Not reported)	Hysteroscopic	47	12 m	NR
7	Cohen [96]	Retrospective	39 (Not reported)	Hysteroscopic	18 14 spontaneously 4 IVF	12 m	16 ➔ CS 2 ➔ miscarriage
8	Tsuji [97]	Retrospective	38 (Not reported)	Hysteroscopic	27 Spontaneous: 8 IVF: 18 IUI: 1	40 m	23 ➔ CS 3 ➔ miscarriage 1 ➔ still ongoing
9	Zeller [98]	Retrospective cohort study	29 (Not reported)	Hysteroscopic	19 Spontaneous: 12, COH: 1 IUI: 1 IVF: 5	12.7	17 ➔ CS 3 ➔ vaginal 3 ➔ ongoing pregnancy 3➔ miscarriage 7 pregnancies of non-infertile participants
10	Szafarowska [99]	Prospective cohort study	44 (Unexplained)	(a)25-Hysteroscopic (b)19-expectant	a) 13 b) 5 Spontaneous: 12 IVF: 6	6 m	Not Reported
	Laparoscopic approach						
11	Donnez [81]	Prospective cohort study	18 (5 unexplained, Other not analyzed)	Laparoscopic	8	Up to 6 y	8 ➔ CS
12	Zhang [100]	Retrospective cohort study	26 (Not reported)	Laparoscopic	12	NR	10 ➔ CS 1 ➔ abortion for congenital anomalies 1 ➔ CS pregnancy
	Transvaginal approach						
13	Deng [101]	Retrospective	124 (Not reported)	Transvaginal	93 pregnancies in 83 women	14.2	40 ➔ still pregnant 28 ➔ CS delivery 4 ➔ vaginal delivery 4 ➔ tubal ectopic pregnancy 2 ➔ CS scar ectopic 14 ➔ miscarriage 1 ➔ induced abortion (CFMF)

No	Author	Study design	No. of infertile patients (Cause)	Approach	No pregnant postoperative	Time of follow-up	Reported outcome of pregnancy
	Multiple approach						
14	Tanimura [90]	Prospective cohort study	4 (unexplained)	Hysteroscopic	4	12 m	4 ➔ cs
			18 (16 unexplained, 1 male, 1 tubal factor)	Laparoscopic	10		8 ➔ cs 2 ➔ miscarriage
15	Zhou [102]	Retrospective cohort study	28 (Not reported)	Hysteroscopic	15	18 m	10 ➔ cs
			35 (Not reported)	Transvaginal	25		23 ➔ cs
16	Enderle [103]	Retrospective cohort study	4 (Not reported)	Hysteroscopic	4 (100)	15	3 ➔ miscarriage 1 ➔ CS
			3 (Not reported)	Transvaginal	3 (100)		2 ➔ Miscarriage 1 ➔ CS
			3 (Not reported)	Laparoscopic	3 (100)		1 ➔ miscarriage 2 ➔ CS

Abbreviations

CS	Cesarean section
CSD	Cesarean scar defect
CSDi	Cesarean scar disorder
GIS	Gel infusion sonography
SHG	Sono-hysterography
RMT	Residual myometrial thickness
AMT	Adjacent myometrial thickness
P	*P* Value
OR	Odds ratio
LUS	Lower uterine segment
WHO	World Health Organization
3D	Three-dimensional
TV/US	Transvaginal ultrasound
PMS	Postmenstrual spotting
VTS	Volume, Thickness, Supplementary features
3D-SHG	Three dimensional sono-hysterography
HSG	Hysterosalpingography
MRI	Magnetic resonance imaging
RCT	Randomized controlled trials
CFMF	Congenital fetal malformations
NR	Not reported

Acknowledgements
We are most grateful to Assiut University for conducting this research.

Authors' contributions
All authors read and approved the final manuscript. MZ: Study design, protocol writing, resolving conflicts and approval of the final version of the manuscript. AM: Database searching, study screening and selection, data analysis, and approval of the final version of the manuscript. AR: Writing the manuscript, data extraction, and approval of the final version of the manuscript. MA: Study design, protocol writing, resolving conflicts, and approval of the final version of the manuscript.

Funding
No fund.

Availability of data and materials
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 20 February 2024 Accepted: 21 May 2024
Published online: 31 May 2024

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