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Uterine scar rupture - Prediction, prevention, diagnosis, and management

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A B S T R A C T

The increasing rate of elective and indicated caesarean sections worldwide has led to new pathologies and management challenges. The number of patients undergoing trial of labor after caesarean section (TOLAC) is also increasing. Three professional societies provide detailed guidelines based on scientific evidence for the management of patients attempting vaginal birth after caesarean section (VBAC). However, they do not provide any recommendations for the actual surgical steps to be followed to minimize the risks of uterine rupture (UR) during TOLAC. Uterine scar condition, intrapartum management and maternal health status correlate to uterine scar rupture risk and provide guidance for parturient TOLAC eligibility. TOLAC and vaginal delivery success rate as reported by the largest studies is between 60% and 77%. Uterine rupture is more prevalent in VBAC-2 patients (1.59%) in contrast to VBAC-1 (0.72%). Additionally, VBAC-2 patients have higher incidence of caesarean hysterectomy 0.56% vs. 0.19% for VBAC-1. The chances of successful VBAC increase when the interpregnancy/interdelivery interval is less than 6.3 years and less than 24 months, respectively. No difference was detected between the techniques of uterine incision closure of the previous CS and TOLAC results, although closure of the CS uterine incision in 2 layers seems to be practiced more widely. Niche or isthmocele presents another complication of CS. Secondary infertility due to niche, will eventually direct to hysteroscopic or laparoscopic repair, depending on the residual myometrial thickness (RMT) as measured by US scan. When RMT is below 3 mm or 2.5 mm

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surgery can be performed, to prevent any spontaneous UR in case of pregnancy. Monitoring by US scanning of hysterotomy scar after myomectomy can detect hematoma. In patients with severe postoperative pain but hemodynamically stable follow up by US scan examination can direct the management decision. In those patients with active bleeding and deterioration of hysterotomy scar edema will be an indication to surgery. There is no firm evidence regarding which type of thread, knotting or sequence of suturing is more favorable to reduce the risk of UR after VBAC or hysterotomy after myomectomy.

Introduction

Uterine rupture is an infrequent yet sometimes fatal complication of a subsequent vaginal birth attempt following a previous cesarean section. In the UK, it has a frequency of 0.2% in women with previous caesarean and 2 in 10,000 overall maternities [1].

Clinically significant uterine scar rupture is defined as a full thickness tear of the uterine wall that also includes uterine serosa (overlying peritoneum). It is associated with fetal distress, the need for an emergency cesarean section, hysterectomy or uterine repair, severe uterine bleeding, protrusion/expulsion of the placenta and/or fetus into the abdominal cavity.2 Interestingly, uterine scar dehiscence (tearing or separation of a pre-existing uterine scar) is much more common but rarely results in major fetal and maternal complications.

Uterine scar dehiscence does not involve the overlying visceral peritoneum, nor does it cause severe bleeding from the peripheries of the pre-existing uterine scar. Additionally, in cases of uterine dehiscence (as opposed to uterine rupture), the umbilical cord, fetus, and placenta remain encased within the uterine cavity. If cesarean delivery is required, it is for separate obstetric reasons and not for fetal distress as a consequence of uterine disruption [2]. Uterine scars themselves can be a result of hysterotomy after abdominal/hysteroscopic myomectomy or adenomyoma excision and after caesarean section (CS) or hysteroscopic surgery of congenital uterine malformations, such as uterine septum and T-shaped uterus.

The current trend of increasing maternal age for the first pregnancy has resulted in, at least partly, a rise in fertility problems [3]. Furthermore, a high number of fertility-treated patients prefer delivery by an elective CS. This, accompanied by modern societal attitudes toward CS delivery, may account for the increasing CS rate worldwide [4]. As a result of the increasing number of CSs, more patients with gynecological or infertility problems are diagnosed with an isthmocele or niche - a condition secondary to previous cesarean section and diagnosed by ultrasound scanning. This is the former area of a uterine lower segment incision with thinning of the myometrium at the anterior wall of the cervicouterine junction, it bares serious management consideration and is also discussed in detail in this review [5]. Readily available 2D and 3D ultrasound scans contribute enormously to the diagnosis of congenital uterine anomalies and myometrial pathologies. Fibroids, adenomyoma, and sub-endometrial adenomyotic lesions can all be diagnosed in the infancy of their development. Consequently, this increases their reported incidence and more patients then undergo uterine surgery.

An outline of the surgical techniques during gynecological surgery, uterine scar rupture prevention and management with their effect on vaginal delivery outcome has been provided. Additionally, the relationship between myometrial defects after CS or hysterotomy after myomectomy and their respective outcomes have been reviewed. Overall, this article aims to critically appraise the current literature available to clinicians and surgeons on this topic and to draw any potential conclusions on best practice, to prevent and decrease fetal and maternal mortality due to uterine scar rupture.

Materials and methods

PubMed and Hunter (St George's Hospital, University of London library) database searches were performed in an iterative manner during May–October 2018 to source articles relating to uterine rupture and associated outcome. Specific scientific journals were accessed, both web-based and print-based. Main titles included: British Journal of Obstetrics and Gynaecology, American Journal of Obstetrics and Gynaecology, Journal of Obstetrics and Gynaecology Canada, International Journal of Gynaecology and Obstetrics, Journal of Perinatology, Seminars in Perinatology and Journal of Maternal-Fetal and Neonatal Medicine.

Inclusion criteria consisted of articles and peer-reviewed journals written as far back as 2007 to ensure that papers reflected recent scientific research and understanding. Journal articles were derived from numerous fields across medicine: obstetrics and gynaecology, perinatology, midwifery, and nursing journals. The reference lists for each relevant article were also reviewed thoroughly to find additional papers. The relevance of sourced articles was investigated, and key findings were documented. Fig. 1 details our selection process.

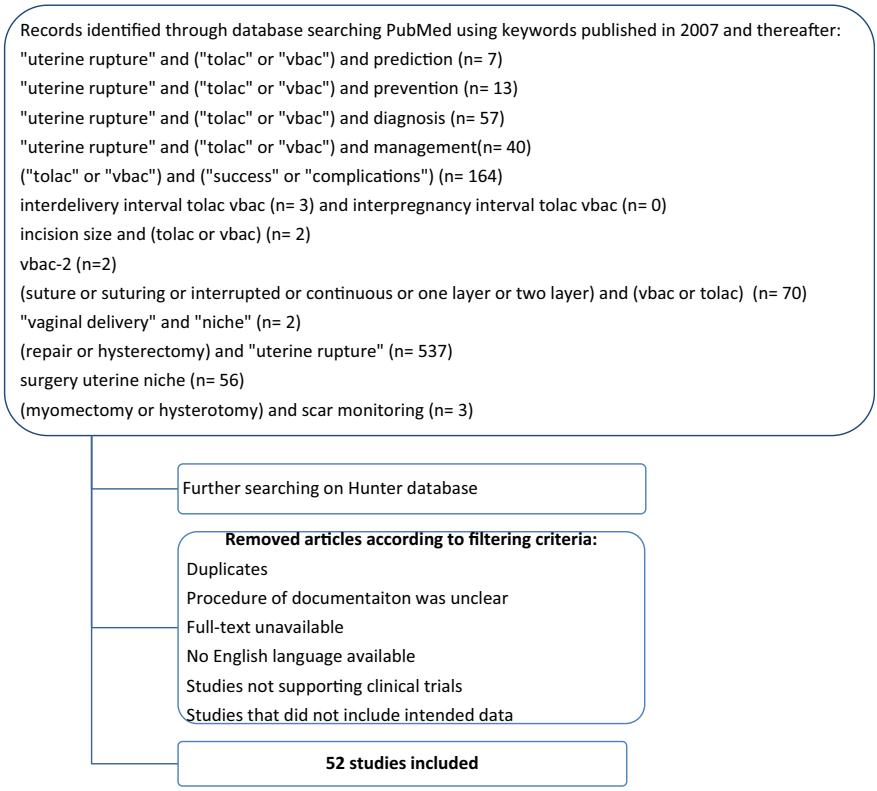

Fig. 1. Diagram of the methodology followed for the screening and identification of literature related to uterine incision articles. A literature search was conducted and a series of conclusions were drawn based on subsequent findings. 13 individual searches resulted in a total of 52 articles that matched our criteria. Summarized findings: 1) Selection of patients based on type of uterine incision of previous cesarean section, Bishop score and estimated fetal weight are the most significant determinants for TOLAC success. 2) The chances of successful VBAC increase when the interpregnancy/interdelivery interval is less than 6 years and less than 24 months respectively. 3) Cases with diagnosis of niche, the residual myometrial thickness and symptomatology of the patient dictates surgical management options. 4) US scan can diagnose hysterotomy wound hematoma in severe post-operative pain following myomectomy.

Characteristics of selected studies

In total 52 articles were included from our searches in our review.

A total of 117 studies matched our criteria for the assessment of trial of labor after caesarean section (TOLAC) failure and complication rates, the eight largest studies were included and risk factors for a negative outcome extrapolated. Three retrospective cohort studies [6–8], three analyses of cohort data [9–11], one analysis of a birth registry [12] and one analysis of prospective multi-center data [13].

The interdelivery/interpregnancy time length and their effects on TOLAC success was reported in 18 studies. After exclusion of duplicates and a thorough review based on our criteria, six papers were included. One study detailing a positive outcome based on interdelivery/interpregnancy length was included (retrospective observational study) [14]. One study highlighting no difference in outcome (prospective observational study) [15], three depicting positive outcomes (retrospective cohort study, analysis of discharge files, cross-sectional study) [16–18] and one detailing both negative and positive (retrospective cohort study) [8].

Variables affecting TOLAC success rate matching our criteria detailing were isolated in 16 studies. Five retrospective cohort studies [14,16,19–21], five prospective observational studies [15,22–25] and two secondary analyses of retrospective cohort studies [6,8]. A systematic review with a meta-analysis [26] was also included plus a cross sectional study [18], prospective cohort study [27], and analysis of discharge files [17].

A search gathering articles pertaining to the correlation between niche patient symptoms and post-operative fertility outcomes was conducted and five papers were included. One observational study and prospective evaluation [28], two prospective studies [29,30], one prospective cohort study [31] and an additional cross-sectional study [32]. Symptoms discussed were abnormal uterine bleeding (spotting), chronic pelvic pain, dysmenorrhea, infertility, and dyspareunia. Outcomes measured included pregnancy rate, live birth rate, VD, and spontaneous abortion rate. Ectopic pregnancy rates were not examined in these studies.

The method of suturing for first CS and its effect on outcome was also searched for and 14 studies matched our criteria. A population based case control study [33], report [34], survey [35], case control study [36], two retrospective cohort studies [37,38], prospective longitudinal study [39], randomized control trial [40], randomized double blinded trial [41], two meta-analyses [42,43], a multi-center case control study [44], an analysis of medical reports [45], and a retrospective medical documentation analysis [46].

The residual myometrial thickness (RMT) as an indication for surgery in cases of uterine niche was also explored. Seven studies satisfied our criteria and were three prospective cohort studies [47–49], prospective longitudinal study [50], two case series [51,52] and one retrospective cohort study [53]. Studies recommended one of two surgical options for treatment – laparoscopic and/or hysteroscopic.

Two papers matched our search criteria that assessed the effect on success rate for patients with a history of one or two cesareans. A systematic review with a meta-analysis of 27 studies [26] and a retrospective cohort study [54] consisting of 62,439 patients. The uterine rupture rate and hysterectomy rate was also examined by the systematic review.

Two studies fulfilled our criteria for a search surrounding scar monitoring recommendations following a myomectomy or other hysterotomy scar. A prospective cohort study [55] and case series [56], 210 patients were included in these studies. Our search examining incision size of previous scar and its effect on TOLAC outcome returned one article matching our search criteria. A randomized prospective cohort study [57] with 600 patients was included.

The guidelines on TOLAC from three prominent professional bodies were included: Royal College of Obstetrics and Gynaecology [58], American College of Obstetrics and Gynaecology [59], Society of Obstetricians and Gynaecologists Canada [60].

Results

Eight articles reported on TOLAC success, complication and failure rates. A nested case-control study [19] by Rohn et al. with 25,005 patients used the same cohort study by Srinivas et al. [6] demonstrating a composite outcome of 2.1% complication rate after TOLAC. Results of the eight studies are outlined in

Table 1. The total number of patients included in these eight studies was 1,209,042 and the total number of patients attempting TOLAC was 368,541. The average success rate of vaginal delivery was 70%. The average complication rate and/or failure of vaginal delivery (VD) was 30%.

Prevention

Five studies consisting of 5123 patients assessed niche patient symptoms and their postoperative fertility outcomes. Different articles addressed different symptoms and results, which are summarized in Table 6. The average rate for patients presenting with abnormal uterine bleeding was 65%, chronic pelvic pain 46.2%, dysmenorrhea 52%, infertility 71.5%, and dyspareunia 24.2%. Following surgery, the average pregnancy rate for niche patients was 72.2% and the live birth rate among those who conceived 95.1%. The vaginal delivery rate was found to be 48% as reported by only one article [29], while two articles reported no vaginal delivery after niche repair in 38 and 41 patients, respectively [28,30]. The spontaneous abortion rate was 9.8% as reported by only one group [30], while there were no reports found concerning the risk of ectopic pregnancy.

The RMT as an indication for surgery in uterine isthmocele or niche was investigated in four prospective [47–50], two case series [51,52], and one retrospective cohort study [53] with a total of 225 patients (Table 7). Two papers supported a cut-off of <3 mm RMT for laparoscopic surgery management [48,51], one advocated <2.5 mm [47] and another <2 mm [50]. Hysteroscopic management was suggested by one paper at >2.5 mm and <2.5 mm [47], with another supporting this technique for all patients with and RMT >2.5 mm [53]. Surgical management was recommended at <2.2 mm RMT by one paper [49] and >2 mm by another [52].

Table 1
TOLAC and vaginal delivery success rate as reported by the largest studies.

Author(s)	Study type	Patients number	Patients TOLAC	Success VD	Complication and/or failure of VD	Risk factors
Chen, HY et al. (2013) [9]	Analysis of cohort data	164,113	164,113	59%	41%	Induction or stimulation of labor *(Infant mortality is significantly higher in women undergoing labor who have a failed TOLAC)*
Knight, HE et al. (2014) [10]	Cohort study	143,970	75,086	63.4%	36.6%	Risk factors: 1) Black women 2) Emergency CS for 1st birth. 3) Giving birth more than 3 years after the 1st baby was born. 4) GDM, PROM, LGA,
Fagerberg, MC et al. (2012) [12]	Swedish Birth Registry	413,696	29,583	71.4%	28.60%	1st CS was indicated for DM or GDM. LGA (or suspected >4.5 kg)
Gregory, KD et al. (2008) [11]	Population cohort study	41,450	41,450	66.8%	33.2%	Maternal soft tissue disorder, malpresentation, other uterine scar, chorioamnionitis.
Srinivas, SK et al. (2007) [6]	Secondary analysis of a retrospective cohort study	25,005	13,706	75.4%	24.6%	Maternal obesity. Pre-gestational diabetes. Increasing number of prior CSs. Fetal macrosomia. Prior CS for cephalopelvic disproportion. Increasing maternal age.
McPherson, JA et al. (2014) [7]	Retrospective cohort study	17,740	17,740	73.2%	26.8%	Advanced maternal age (≥35 y). BMI ≥30 kg/m2. Black women.
Mercer, BM et al. (2008) [13]	Prospective multicenter data	378,063	13,532	71.8%	28.2%	No prior VBAC.
Stamilio, DM et al. (2007) [8]	Multi-ctr, retrospect. cohort	25,005	13,331	77%	23%	<6 months interval > risk of UR, blood transfusion and composite outcome.

Index: CS – Caesarean section, GDM – Gestational diabetes, PROM – Premature rupture of membranes, LGA – Large for gestational age, DM – Diabetes mellitus, VD – Vaginal delivery.

Table 2
Conditions associated directly and indirectly to uterine scar and anticipated uterine rupture risk. (Data extracted from the recommendations for successful and safe TOLAC by 3 leading professional societies).

	RCOG [58]	ACOG [59]	SOGC [60]
Factors directly correlated to uterine scar condition and risk for uterine rupture			
Maternal age increases the risk	Maternal age ≥ 40,	↑ Maternal age	Limited data
Inter-delivery time and UR	<12 m, UR risk increased	<19 m VBAC chance is ↓	18–24 m risk↑
Women with >1 previous CS	Decision for TOLAC: senior Dr	Allowed TOLAC	Higher risk of UR
Number of previous uterine scars and/or previous CS	Increased risk of UR	Increased risk of UR	>1 previous CS
Type of previous CS incision	Least risk: lower segment CS	Highest risk: *trans*-fundal or classical or T shape	Least risk after LTCS
Scar myometrial thickness in US	Decreased = higher risk UR	No statement	Decreased = higher risk UR
Intrapartum management and uterine scar risk for uterine rupture			
Oxytocin for augmentation	Decision by a senior Dr	With caution	With caution
Prostaglandin E1	No statement	Contraindicated	Contraindicated
Prostaglandin E2	Decision by senior Dr	Not recommended	Contraindicated
Foley catheter to ripen cervix	Can be used	Can be used	Can be used
Pre-labor Bishop score	Lower higher the risk of UR	No statement	No statement
Maternal conditions and uterine scar risk for uterine rupture			
Multiple gestation	VBAC success rates similar to single gestation	Can undergo TOLAC	Not a CI to TOLAC
Diabetes Mellitus	No statement	No statement	Not a CI to TOLAC
Suspected fetal macrosomia	>4 kg risk for UR increased, caution	Not a CI to TOLAC	Not a CI to TOLAC
Postdate pregnancy	Increases UR risk	VBAC success decreased	TOLAC is allowed
Obesity	Increased risk for UR	Increased risk for UR	Limited data
Pre-eclampsia	Decision by a senior Dr	Increased risk for UR	No statement
Epidural analgesia is not CI	Higher doses needed might anticipate UR	No link with unsuccessful TOLAC	Not contraindicated
Antenatal care schedule & clinical care pathway	VBAC checklist	No statement	No statement
Documentation -previous CS	Required	Required	Required

Index: *CI = contraindicated.

The number of patients included in these studies is small; however, all four prospective studies [47–50] seem to be in consensus as to patients that present with an RMT of less than 3 mm warrant laparoscopic resection of the scar. Regarding vaginal delivery after niche repair, only one cohort study consisted of patients undergoing a successful VD [29] (162 patients VD rate: 48%), while another two studies [28,30] did not allow patients to undergo VD. Regarding CS incision size, it has been suggested that modified CS techniques such as a Joel-Cohen incision, non-closure of the peritoneum, exteriorized full thickness suturing of the uterine incision could potentially decrease long-term morbidities of the procedure [57]. It is to be noted that the minimal myometrial thickness that does not pose a risk for uterine rupture during vaginal birth attempt in women with a history of cesarean section is 2.8 mm [27].

The outcome of TOLAC in correlation to the suture technique for prior cesarean was investigated by 14 studies involving 96,104 patients overall (Table 5). The majority of the studies (seven) among them one randomized double blinded study [41] and two meta-analysis [42,43], reported that double layer uterine closure of the previous CS was safer for TOLAC than single layer closure. A report [34], one retrospective [46], and one prospective longitudinal study [39] of 60 patients supported closure of the uterine incision by single layer as the best option for a safer subsequent TOLAC. A RCT with 15,935 patients [40], one multi-center [44] and one case control trial [36] with 22,817 and 39,742 cases, respectively, and a cohort study [38] found no difference between the techniques of uterine incision closure of the previous CS and TOLAC results.

One paper (survey of surgeon's preferences) [35] supported locked suturing versus one other (meta-analysis) [43] that supported unlocked; a retrospective cohort study found no difference between the two techniques [38]. A report recommended delayed absorbable suture polyglactin 910 (0) or PGA (0)

Table 3
Interpregnancy/Inter-delivery interval and the effect on VBAC.

Author	Study type	Study patients	Patients attempting TOLAC	Successful VBAC	Negative Outcome
Viteri, O et al. (2015) [15]	Prospective observational	36,983	4575	No association with time and outcome when >24 m - 59.9% when <24 m - 64.1%	>24 m, ↑ emergency CS, operative injury, ↓ transfusion, UR, post-partum endometritis, Hysterectomy, readmission rate, death rate Non-significant
Manzanares, S et al. (2018) [14]	Retrospective observational	2367	2367	<6.3 m - 62.3%	BMI > 25, non-spont onset of labor, fetal wt > 3775,
Rietveld, AL et al. (2017) [16]	Retrospective cohort	36,653	36,653	<24 m - 70–72% >24 m - 62–70%	
Siddiqui, SA et al. (2013) [18]	Cross-sectional study	2377	122	<2 years - 72%	
Barger, MK et al. (2012) [17]	Analysis of discharge files	1526	347	<18 m - 75.2%	
Stamilio, D et al. (2007) [8]	Multi-ctr, retrospect. cohort	25,005	13,331	>6 m - 77%	<6 months ↓ UR, blood transfusion, [a]composite morbidity

Index: Negative outcome = Failed TOLAC or UR; hysterectomy, need for mechanical ventilation or a blood transfusion or a maternal death).
[a] Composite morbidity = Uterine Rupture, Bladder, ureter, or bowel injury, uterine artery laceration m = months.

with an analysis of medical reports showing no significant difference between suture material [45]. Additionally, mattress suturing was recommended by one paper [34]. Regarding the discussion between the use of chromic catgut and polyglactin 910 no significant difference was shown by a randomized control trial [40]. Continuous stitching was recommended by two papers [34,35] and

Table 4
Variables affecting TOLAC success.

Factor	Favors TOLAC outcome	Negatively affects outcome	Study
Previous vaginal delivery	Yes		Rohn, A et al. (2008) [19], Grobman, W & Lai, Y et al. (2007) [22], Srinivas, S et al. (2007) [6]
Higher No of previous CS		Yes	Tahseen, S et al. (2009) [26]
Shorter inter-P/D interval	Yes		Reitveld, AK et al. (2017) [16], Manzanares, S et al. (2018) [14]
		Yes	Siddiqui, SA et al. (2013) [18], Barger, MK et al. (2012) [17], Stamilo, D et al. (2007) [8]
	Higher incidence of emergency CS and operative injury in >24 m pregnancy interval (No statistical significance)		Viteri, O et al. (2015) [15]
Single uterine closure technique (prior CS)		Yes	Durnwald, C and Mercer, B (2008) [23]
Previous preterm CS		Yes	Sciscione, A et al. (2008) [24]
	Pre-term CS associated with ↑ maternal age, GA at delivery for current pregnancy, higher prior vaginal delivery, ↓ maternal gravidity,		Harper, L et al. (2009) [20]
Induction of labor		Yes	Grobman, W et al. (2007) [25], Cahill, A et al. (2007) [21], Rohn, A et al. (2008) [19], Srinivas (2007) [6]
Augmentation of labor		Yes	Rohn, A et al. (2008) [19]
LUS Mm thickness in US < 2.3 mm		Yes	Bujold, E et al. (2009) [27]
History of abdominal surgery		Yes	Rohn, A et al. (2008) [19]

Index: inter P/D interval = inter-pregnancy/inter delivery interval, GA = gestational age, LUS Mm = Lower Uterine Segment Myometrial.

Table 5
Suture technique at CS and effect on outcome.

Author	Study Type	Sample Size	Single Layer (+)	Double Layer (+)	Comment
Yasmin, S et al. (2011) [41]	Randomized double blinded trial	90		✓	
CORONIS, 2013 [40]	RCT	15,935			NDF between single or double layer or threads vicryl or catgut
Ceci, O et al. (2012) [39]	Prospective longitudinal study	60	✓		Favors interrupted suturing
Roberge, S et al. (2011) [43]	Meta-analysis	6386		✓	Favors unlocked
Roberge, S and Bujold, E (2009) [42]	Meta-analysis	5788		✓	
Thisted, D et al. (2017) [33]	Population-based case-control study	39,742			NDF between single or double layer
Defline, A et al. (2014) [44]	Multicenter case-control study	22,817			NDF between single or double layer
Bujold, E et al. (2010) [36]	Case control study	384		✓	
Hudic, I et al. (2012) [38]	Retrospective cohort study	388			NDF between locked and unlocked suturing
Glavind, J et al. (2013) [37]	Retrospective cohort study	149		✓	
Hudic, I et al. (2010) [46]	Retrospective document analysis	448	✓		
Vachon-Marceau, C et al. (2017) [45]	Analysis of medical reports	1613		✓	NDF among threads
Babu, KM and Magon, N (2012) [34]	Report	50	✓		Favors continuous + delayed absorbable mattress
Demers, S et al. (2013) [35]	Survey (Doctors preference)	454		✓	Favors continuous and locked

Index.
✓ = in favor; NDF = no difference found.

interrupted stitching by just one [39]. The type of suture, knotting and sequence technique, interrupted or mattress, and locked or unlocked were all reported in the studies without any significant comment on pros or cons.

Prediction

The conditions associated with uterine scar formation and anticipated uterine rupture risk were reported in the form of key statement recommendations by three gynecological societies: RCOG, ACOG and SOGC. The factors that directly correlated to uterine scar condition and higher risk for uterine rupture include: higher maternal age [58,59], women with >1 previous CS [58,60], number of uterine scars and/or previous CS [58–60], type of previous CS incision [58–60], and decreased scar myometrial thickness on ultrasound [58,60].

The interpregnancy/interdelivery interval and the effect on VBAC was reported by six studies with a total patient population of 104,911 as shown in Table 3. The average number of patients attempting TOLAC was 57,395. The likelihood of a successful VBAC increased when the interpregnancy/interdelivery interval was less than 6.3 years and less than 24 months. In one prospective study non-significant correlations were found, there was no association between time and positive VBAC outcome [15]. Patients with an interval >24 months had higher rates of emergency CS and operative injury and lower rates of transfusion, UR, postpartum endometritis, hysterectomy, readmission and mortality, when compared with their <24 month interval counterparts [15]. Associations with a negative TOLAC outcome included patients having a BMI >25, nonspontaneous onset of labor, fetal weight >3775 g and <6.3 years time interval [14].

Patients having a previous vaginal delivery were more likely to have positive TOLAC outcome [6,19,22], along with those who had a shorter interpregnancy/interdelivery interval [14,16]. Negative outcomes were associated with a higher number of previous CSs [26], a single uterine closure

Table 6
Niche patient symptoms and postoperative fertility outcomes. Diagnostic criteria: women with a history of Caesarean section were screened using transvaginal ultrasound and/or gel instillation sonohysterography (GIS). Caesarean scar defect was diagnosed by the presence of a hypoechogenic area (filling defect).

Study	Study Type	Patients	Symptoms					Infertility Obst Results		
			AUB %	CPP %	Dysm/a	Infertility %	Dysp/a %	PR %	LBR %	VD
Donnez, O et al. (2017) [28]	Observational & prospective evaluation	38	60.5	52.6	50	43	30	44.4	100	0%
Osser, O et al. (2011) [29]	Prospective cohort study	162	–	–	–	–	–	–	–	50% SD, 46% LD
Gubbini, G et al. (2011) [30]	Prospective study	41	100	46.3	–	100	–	100	90.2	0%
Bilj de Vaate, A et al. (2010) [31]	Prospective cohort study	632	33.6	–	–	–	–	–	–	–
Wang, C et al. (2009) [32]	Cross-sectional	207	63.8	39.6	53.1	–	18.3	–	–	–

Index: AUB = abnormal uterine bleeding, CPP = chronic pelvic pain, Dysm/a = dysmenorrhoea, Dysp/a = dyspareunia, PR = pregnancy rate LBR = Live birth rate, VD = vaginal delivery.

technique used for the prior cesarean section [23], previous preterm CS [24], induction and augmentation of labor [6,19,21,25], lower uterine segment (LUS) thickness <2.3 mm [27] and a history of previous abdominal surgery [19] as demonstrated by Table 4.

The number of previous cesarean sections and VBAC success rate, uterine rupture, and subsequent hysterectomy were investigated among 57,017 patients by a systematic review [26]. The VBAC success rate was 76.5% after 1 CS and 71.1% after 2 CSs, while the uterine rupture rate after VBAC from 1 CS was 0.72% and 1.6% after 2 CSs. The cesarean hysterectomy rate after VBAC for 1 CS was 0.19% and 0.56% after 2 CSs.

TOLAC management

Regarding intrapartum management and uterine scar and rupture risk, five factors were addressed by the three societies, including the use of oxytocin [58–60], prostaglandin E1 [59,60], and prostaglandin E2 [58–60], as well as a pre-labor poor Bishop score [58]. The factors were all associated with increased risk of UR. Mechanical ripening of cervix was accepted by all societies as a safe measure [58–60]. The maternal conditions contributing to uterine scar and rupture risk were addressed by the societies with variable statements and level of significance including multiple gestation, diabetes mellitus, suspected fetal macrosomia, postdate pregnancy, obesity, and preeclampsia [58–60]. All 3 societies converged that epidural analgesia is not contraindicated during TOLAC, and an antenatal care schedule with clinical care pathway and documentation of previous CS are required [58–60]. Table 2 presents the conditions associated directly and indirectly to uterine scar and anticipated uterine rupture risk.

Table 7
Residual myometrium thickness as an indication for surgery in cases of uterine niche.

Reference	Patients	Study Type	RMT Measurement for Surgery	
			Laparoscopic	Hysteroscopic
Tanimura, S et al. (2015) [47]	22	Prospective cohort	<2.5 mm	>2.5 mm & <2.5 mm[a]
Vervoort A et al. (2017) [48]	101	Prospective cohort	<3 mm	
Pomorski, M et al. (2017) [49]	7	Prospective cohort		<2.2 mm
Dosedla, E and Calda, P (2017) [50]	11	Prospective longitudinal	<2 mm	
Marotta, M et al. (2013) [51]	13	Case series	<3 mm	
Jeremy, B et al. (2013) [53]	14	Retrospective cohort		>2.5 mm
Chang, Y et al. (2009) [52]	57	Case series		>2 mm

[a] For patients with an RMT <2.5 mm both laparoscopic and hysteroscopic management was selected, but for patients with an RMT of >/ = 2.5 mm only hysteroscopic management was used.

Discussion

Prevention of uterine rupture

The rates of delivery by cesarean section have continued to increase, which has attracted much attention to long-term sequela, which can adversely affect subsequent pregnancies. Reports on the incidence of niches have produced conflicting results, and the rates vary between 6.9% and 69% [61]. Data suggest the development of isthmoceles occurs in approximately 60% of patients after a primary cesarean section and 100% after 3 CSs [62]. Minimizing the risk factors for niche such as prolonged labor, cervical dilatation, induction of labor, augmentation of labor with oxytocin, diabetes, failure to progress to the third stage, fever, and blood loss may reduce the incidence rate [63]. The pathogenesis and formation of niche are still under investigation. Two types of post CS scar defects have been reported: a) with a valve-like mechanism closing the pouch and resultant accumulation of hemolyzed blood and b) with thick vessels penetrating the bottom of the pouch, forming a dome-like structure [64]. Symptoms may be related to an incompletely healed cesarean scar, postmenstrual spotting, vaginal discharge, chronic pelvic pain, dysmenorrhea, dyspareunia, hypogastric pain, infertility, micturition disorders, and abnormal uterine bleeding after entrapment of menstrual blood causing postmenstrual spotting [62].

Hormonal menstrual suppression (oral contraception) provides treatments of pain and dyspareunia [65].

Hysterectomy may be offered to patients without any need of fertility preservation while hysteroscopic and/or laparoscopic surgery can treat infertility patients.

Hysteroscopic surgery of a niche consists of loop resection of the pouch to reduce its depth [65]. The technique involves resection of the anterior edge of the lesion, which appears like a flap underneath the triangular pouch, facilitating menstrual flow drainage through the cervix. Ablation of the superficial dilated blood vessels inside the pouch prevents the in-situ production of serosanguinous fluid [66]. Other surgical techniques include resection of the inferior and superior edges of the defect using a cutting bipolar loop, fibrotic scar tissue is then completely resected, exposing the muscular tissue below. The edges of the diverticulum are then removed, leveling its wall, ensuring continuity to the cervical canal [67].

Laparoscopic treatment of niche starts from the accurate diagnosis of the location and extent of the defect by combined hysteroscopic and laparoscopic *trans*-illumination. Concurrent laparoscopic and hysteroscopic assessment of the repair is done by ensuring that no hysteroscopic fluid escapes from the site of repaired hysterotomy [68]. A bladder flap is then developed by opening the vesicovaginal and vesicocervical space, mobilizing the bladder inferiorly. With the guide of the hysteroscopic mapping of the defect, the fibrotic edges of the niche are excised with thermal energy or sharp dissection. Identification of the healthy myometrial tissue margins and re-approximation of the margins with absorbable suture (2-0 polyglactin) are usually done in an interrupted or running fashion, often in 2 layers. Following laparoscopic repair, hysteroscopic evaluation of the uterine cavity is performed to assure complete resolution of the defect [50].

The myoma number, size and location, correct cleavage plain identification, and incomplete excision are the main factors undermining the strength of the uterine muscle during myomectomy. When adenomyosis is a concern, the depth and extension of the disease, the time to local inflammation exposure, degree of extirpation of the adenomyosis present the risk factors in weakening the uterine muscles. Postoperative hematoma formation and wound infection, excessive cauterization, and suboptimal uterine wall approximation, present common risk factors for postoperative uterine rupture in a gravid uterus for both myomectomy and adenomyosis surgery [69–71].

Adenomyosis

In postadenomyotic reductive surgeries, pregnancies are associated with thinning of the uterine walls, high miscarriage rate and silent uterine ruptures during the midterm pregnancy. Higher incidence of placenta accreta and percreta has been also observed when compared with cases after cesarean section and myomectomy [72].

Adenomyosis partial reductive surgery can be performed by laparoscopy or laparotomy and fertility results have been reported between 21% and 38% across the different techniques. The postoperative clinical effectiveness on dysmenorrhea and menorrhagia is small, and recurrence occurs due to the presence of remaining adenomyomatous tissue [72].

Complete adenomyosis excision Triple-flap technique is effective for diffuse and nodular adenomyosis and involves reconstruction of the uterine wall defect using endometrial uterine muscle flaps, preventing uterine rupture in subsequent postoperative pregnancies. The blood flow in the incision sites returned to normal in 92/113 cases (81.4%) within 6 months and 46/62 conceived and 32 delivered a healthy baby by elective Cesarean section. No case of uterine rupture has been reported [73–75].

Excessive diathermy

High-frequency electrosurgery (HFE) and excessive cauterization are associated with the weakening of the myometrium and most postoperative uterine rupture cases during pregnancy [76,77].

HFE is used in most operative facilities for myomectomies, adenomyoma, and adenomyosis resection. Electrical powered instruments, such as monopolar and bipolar needles, hocks, and lasers are used for hysterotomy as well as for hemostasis and seem to have an advantage over the cold instruments mainly for reduced blood loss. However, after excessive cauterization, adhesions due to high fibrin deposition, tissue hardening, and discoloration make the margins between the normal myometrium and adenomyosis less clear while increasing the risk of wound dehiscence [74,78,79].

Although, HFE usage reduces hemorrhage and operative time, histological examinations revealed delay in wound healing associated with electrocautery, compared with the use of a cold knife surgery [80,81]. Cauterization heat causes denaturation of proteins and clots, highly cohesive agglomerates affecting angiogenesis and tissue healing. Histological examination of the tissues near the uterine rupture sites during pregnancy, in patients that previously underwent myomectomy or adenomyosis resection, reported high collagen concentrations and fewer smooth muscle fibers, suspected contributing to regional weakness of the uterus [78]. HFE accelerates the healing process of the injured site, causes uncontrolled release of Growth factors and excessive collagen deposition resulting to hypertrophic scarring [82].

Injection of ADH (vasopressin derivative solutions) or diluted adrenaline around the fibroid wall or in the margins of an adenomyotic lesion minimizes the bleeding during dissection. Temporary bilateral uterine artery clipping reduces the blood supply and bleeding during myomectomy. Both techniques aim to reduce the hemorrhage during dissection and the extent of electrocauterization usage [69,83].

Control of bleeding is of paramount importance after fibroid enucleation and adenomyosis reductive surgery. Bipolar diathermy is preferable to monopolar, targeting only the big vessels and causing less destruction to healthy myometrium. Hemostasis should be avoided for micro bleeders to facilitate healing process and excessive coagulation and carbonization should be avoided. Using bipolar diathermy, a dissecting grasper, and a suction cannula, meticulous exploration of the dissection field can more efficiently detect and coagulate any actively bleeding vessels [69,84].

Myometrium wound approximation and suturing

Wound healing disorders can also result after inappropriate suturing either because of incomplete tissue approximation or when severe tension sutures are applied. Tissue necrosis, scarring, and excessive collagen deposition contribute to underpowered myometrium, exposed to risk of rupture during pregnancy, labor, and delivery [74,79].

The seromuscular plane must be closed edge-to-edge to avoid leaving any empty space in between sides. The preferable way of suturing is separated single or figure-eight sutures in the myometrial layer and separated or continuous sutures in the serosa. The uterine wound can be closed with single or double layer sutures, depending on the fibroid depth into the myometrium. The decision between single or double layer closure depends on the depth of the wound; whether it is more or less than 50%

of the myometrium. Double layer suturing is preferable in cases of intramural myoma while in case of a sub-serous fibroid, suturing in a single layer is enough [69,85].

When concomitant pathologies exist, such as focal adenomyosis, or in large intramural and submucous fibroid extractions, myometrium approximation becomes a big challenge. Sometimes a gap left between the wound sides is inevitable. Accordingly, a postoperative follow up is recommended and a comment in patient's discharge report is advisable. Particular attention should be taken if decision for spontaneous delivery follows [69].

Poly dioxanol suture (PDS), absorbable poliglecaprone monofilament, vicryl, 0 or 2-0 are usually used for suturing. Barbed sutures can also be used as continuous sutures in the myometrial layer, saving time by eliminating the need for knotting. On the serosa, continuous mattress suturing is also an option, giving a nice edge-to-edge approximation, minimizing the rough area left, and reducing the possibility of forming of adhesions. The suture pedicles should be within the wound. Extracorporeal knotting is the preferred method of knotting in myomectomy since stronger knots might achieve better wound approximation. Skilled surgeons confident in intracorporeal suturing can usually reduce the time spent on suturing [69,85].

Vaginal birth attempts should not be undertaken in women with myometrial thickness lesser than 2.8 mm [27]. In two papers, monitoring by US examination of hysterotomy scar after myomectomy was performed to detect complications, such as postoperative hematoma and heterogeneous/poorly defined scar, as well as signs for myometrial scarring. One paper advocated the use of transvaginal Doppler monitoring to evaluate the pulsatility index (PI) and resistance index (RI) of the uterine arteries to identify patients with abnormal parameters, a potential risk factor for wound healing. Tepper et al. highlighted the importance of careful US examination following myomectomy so as not to mistake effects of surgery (edema, hematoma, and suture material) as remaining fibroid tissue [56].

The risk of uterine scar rupture after CS is very low. Proper surgical techniques should be optimized to minimize the risk of inappropriate wound tissue approximation and infection. Incision size should be according to fetal head dimensions and uterine muscular layers better to sutured in two layers. Penetrance to the endometrial area, locked sutures, and vessel strangulating knots should be avoided because revascularization can be compromised and extended fibrotic tissue may be formed. In cesarean sections after prior delivery of macrosomic fetuses and cases after myomectomies of large myomas or complicated hysterectomies with severe pain after surgery, postoperative ultrasound scan monitoring of the uterine scar is advisable.

Wound monitoring

Literature evidence is lacking regarding monitoring parameters and how often patients should be examined, however post-operative severe and continuous pelvic pain is characteristic of a wound hematoma. An abdominal or transvaginal ultrasound scan will confirm uterine wound integrity, edema, hematoma and diagnose an intraperitoneal hemorrhage. Daily or even twice daily US scan of the wound can monitor hematoma development, the need for reoperation and can provide information later on regarding trial of labor after myomectomy (TOLAM) and or myometrium gap defect. Compromised cardiovascular activity indicates a re-operation. Scar swelling and later scar defect with dehiscence may also be diagnosed [86]. The posterior bladder wall may also be involved within adhesions resulting in micturition problems. When the patient is hemodynamically unstable, laparoscopy should follow. Additionally, when the hematoma is under control, US scan monitoring should be performed the first week every day and then every week until image normalization [70,71].

Prediction of vaginal delivery

The RCOG [58] and ACOG [59] both report the significance of maternal age on TOLAC outcome, the RCOG specifies a maternal age of >40 as having an increased risk of UR. All three societies report the influence of number of previous uterine scars and/or previous CS on UR; the ACOG and RCOG report an increased risk of UR occurrence with an increase in both previous scars and CS while the SOGC

[60] limits the correlation to >1 previous CS. For women with >1 previous CS, the RCOG suggests referring to a senior doctor before making a decision on TOLAC, while the ACOG allows a TOLAC for this group and the SOGC acknowledges increased risk without outlining a specific recommendation. The three societies report differently on the influence of the type of CS: the RCOG suggest the lowest risk of uterine scar formation and rupture to be with lower segment CS, while the ACOG suggest the highest risk to be with *trans*-fundal, classical or T shape. The SOGC assert the lowest risk to be with lower segment cesarean section (LCTS). Finally, the RCOG and SOGC both report the correlation between a decreased myometrial thickness on US and a higher risk of UR.

All three societies approve multiple gestation pregnancies for a TOLAC and the RCOG [58] reports VBAC success rates similar to those in single gestation pregnancies. The SOGC [60] state that maternal diabetes mellitus is not a contraindication to TOLAC, while the RCOG and ACOG [59] do not make any recommendation. Both the ACOG and SOGC recommend that suspected fetal macrosomia is not a contraindication to TOLAC, while the RCOG state that with a fetal weight of >4 kg there is an increased risk for UR and thus caregivers should proceed with caution. Regarding postdate pregnancy, the RCOG reports an increased risk of UR, the ACOG a decreased likelihood of VBAC success, and the SOGC supports a TOLAC for postdate pregnancy. Both the ACOG and RCOG described an increased risk for UR with obesity. The RCOG advocates referring to a senior doctor in cases of pre-eclampsia while the ACOG states there is an associated increased risk of rupture. Regarding an epidural, the RCOG asserts that the patient "need" for higher doses may predict a subsequent UR, while ACOG contends that there is no link with an unsuccessful TOLAC. Similarly, the SOGC does not consider this a contraindication.

TOLAC management

The ACOG [59] and SOGC [60] agree that oxytocin for augmentation is acceptable only with caution, while the RCOG [58] suggest decision by a senior doctor. The ACOG and SOGC report prostaglandin E1 to be a contraindication due to uterine rupture risk. The SOGC reports prostaglandin E2 to also be contraindicated, while the ACOG do not recommend use and also recommend the overall decision to be made by a senior doctor. All three societies are in consensus that Foley catheters can be used to ripen the cervix. Only the ACOG comments on a pre-labor Bishop score, with the counsel that a lower Bishop score predicts higher risk of UR. Only the RCOG recommend a VBAC checklist during antenatal care. All three societies recommend documentation of previous CS.

Conclusive remarks

The increasing rates of delivery by caesarean section have attracted much attention to long-term sequela, which can adversely affect subsequent pregnancies. Secondary infertility due to niche or abdominal adhesions will inadvertently need hysteroscopic or laparoscopic repair depending on the RMT measured by US scan. When the RMT is below 2.5–3 mm surgery should be performed, to prevent any spontaneous UR in case of pregnancy. VBAC is another obstetric challenge patients and clinicians face, it can be affirmed that TOLAC is recommended by 3 professional societies within a frame of standard protocols and strict documentation under the care of senior obstetricians.

Factors which directly affect uterine scar condition, intra-partum management, maternal conditions and their respective contribution to uterine rupture risk have been described in detail. Additionally, guidance for clinicians as to patients' TOLAC eligibility has been provided. TOLAC and vaginal delivery success rate as reported by the largest studies is between 60%. and 77%. The chances of successful VBAC increased when the interpregnancy/interdelivery interval was less than 6.3 years and less than 24 months respectively. Studies assessed found no difference between the techniques of uterine incision closure of the previous CS and TOLAC results, although closure of the CS uterine incision in 2 layers seems to be more widely used.

Practice points

- Selection of patients based on type of uterine incision of previous cesarean section, Bishop score and estimated fetal weight are the most significant determinants for TOLAC success.
- The chances of successful VBAC increase when the interpregnancy/interdelivery interval is less than 6.3 years and less than 24 months respectively.
- Patients with diagnosis of niche, the residual myometrial thickness and symptomatology dictate surgical management options.
- US scan can diagnose hysterotomy wound hematoma in severe post-operative pain following myomectomy.

Research agenda

- A PRCT on risk factors regarding way of suturing and closure of the uterine incision after CS
- A PRCT on risk factors and TOLAC after myomectomy
- A PRCT on hysterotomy after myomectomy and uterine wound US scan monitoring

Conflict of interest

The authors have no conflicts of interest.

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References

[1] Knight M. Uterine rupture is rarer than previously thought | UKOSS | NPEU [Internet]. Npeu.ox.ac.uk [cited 4 June 2018]. 2018. Available from: https://www.npeu.ox.ac.uk/ukoss/news/31-uterine-rupture-is-rarer-than- previously-thought.
[2] Nahum G. Uterine rupture in pregnancy: overview, rupture of the unscarred uterus, previous uterine myomectomy and uterine rupture [Internet]. Reference.medscape.com [cited 4 June 2018]. 2018. Available from: https://reference.medscape.com/article/275854-overview.
[3] [cited 3 November 2018] RCOG statement on later maternal age [Internet]. Royal College of Obstetricians & Gynaecologists; 2018. Available from: https://www.rcog.org.uk/en/news/rcog-statement-on-later- maternal-age/.
[4] [cited 3 November 2018] WHO statement on caesarean section rates [Internet]. WHO.int. 2018. Available from: http://apps.who.int/iris/bitstream/handle/10665/161442/WHO_RHR_15.02_eng.pdf;jsessionid=A276364E4BC86655B042584B49DF0876?sequence=1.
[5] Bij de Vaate A, van der Voet L, Naji O, Witmer M, Veersema S, Brölmann H, et al. Prevalence, potential risk factors for development and symptoms related to the presence of uterine niches following Cesarean section: systematic review. Ultrasound Obstet Gynecol 2014;43(4):372–82.
[6] Srinivas S, Stamilio D, Sammel M, Stevens E, Peipert J, Odibo A, et al. Vaginal birth after caesarean delivery: does maternal age affect safety and success? Paediatr Perinat Epidemiol 2007;21(2):114–20.
[7] McPherson J, Strauss R, Stamilio D. Nonreassuring fetal status during trial of labor after cesarean. Am J Obstet Gynecol 2014;211(4):408.e1–8.
[8] Stamilio D, DeFranco E, Paré E, Odibo A, Peipert J, Allsworth J, et al. Short interpregnancy interval: risk of uterine rupture and complications of vaginal birth after cesarean delivery. Obstet Anesth Digest 2008;28(2):91.
[9] Chen H, Chauhan S, Grobman W, Ananth C, Vintzileos A, Abuhamad A. Association of labor induction or stimulation with infant mortality in women with failed versus successful trial of labor after prior cesarean. J Matern Fetal Neonatal Med 2013;26(12):1162–5.
[10] Knight H, Gurol-Urganci I, van der Meulen J, Mahmood T, Richmond D, Dougall A, et al. Vaginal birth after caesarean section: a cohort study investigating factors associated with its uptake and success. BJOG An Int J Obstet Gynaecol 2013;121(2):183–92.
[11] Gregory K, Korst L, Fridman M, Shihady I, Broussard P, Fink A, et al. Vaginal birth after cesarean: clinical risk factors associated with adverse outcome. Am J Obstet Gynecol 2008;198(4):452.e1–452.e12.

[12] Fagerberg M, Maršál K, Ekström P, Källén K. Indications for first caesarean and delivery mode in subsequent trial of labour. Paediatr Perinat Epidemiol 2012;27(1):72–80.
[13] Mercer B, Gilbert S, Landon M, Spong C, Leveno K, Rouse D, et al. Labor outcomes with increasing number of prior vaginal births after cesarean delivery. Obstet Gynecol 2008;111(2, Part 1):285–91.
[14] Manzanares S, Ruiz-Duran S, Pinto A, Pineda A, Puertas A. An integrated model with classification criteria to predict vaginal delivery success after cesarean section. J Matern Fetal Neonatal Med 2018:1–7.
[15] Viteri O, Chauhan S, Mendez-Tabueroa H, Hammad I, Roberts R, Sibai B. 267: interdelivery interval length and obstetric outcomes during trial of labor after cesarean. Am J Obstet Gynecol 2015;212(1):S146.
[16] Rietveld A, Teunissen P, Kazemier B, De Groot C. Effect of interpregnancy interval on the success rate of trial of labor after cesarean. J Perinatol 2017;37(11):1192–6.
[17] Barger M, Nannini A, Weiss J, Declercq E, Stubblefield P, Werler M, et al. Severe maternal and perinatal outcomes from uterine rupture among women at term with a trial of labor. J Perinatol 2012;32(11):837–43.
[18] Siddiqui S. Obstetric factors for unsuccessful trial of labor in second-order birth following previous cesarean. Ann Saudi Med 2013;33(4):356–62.
[19] Rohn A, Scifres C, Odibo A, Stamilio D, Macones G. 343: predicting major morbidity in women undergoing a VBAC attempt. Am J Obstet Gynecol 2008;199(6):S106.
[20] Harper L, Cahill A, Stamilio D, Odibo A, Peipert J, Macones G. Effect of gestational age at the prior cesarean delivery on maternal morbidity in subsequent VBAC attempt. Am J Obstet Gynecol 2009;200(3):276.e1–6.
[21] Cahill A, Stamilio D, Odibo A, Peipert J, Stevens E, Macones G. Does a maximum dose of oxytocin affect risk for uterine rupture in candidates for vaginal birth after cesarean delivery? Am J Obstet Gynecol 2007;197(5):495.e1–5.
[22] Grobman W, Lai Y, Landon M, Spong C, Leveno K, Rouse D, et al. Development of a nomogram for prediction of vaginal birth after cesarean delivery. Obstet Gynecol 2007;109(4):806–12.
[23] Durnwald C, Mercer B. Myometrial thickness according to uterine site, gestational age and prior cesarean delivery. J Matern Fetal Neonatal Med 2008;21(4):247–50.
[24] Sciscione A, Landon M, Leveno K, Spong C, MacPherson C, Varner M, et al. Previous preterm cesarean delivery and risk of subsequent uterine rupture. Obstet Gynecol 2008;111(3):648–53.
[25] Grobman W, Gilbert S, Landon M, Spong C, Leveno K, Rouse D, et al. Outcomes of induction of labor after one prior cesarean. Obstet Gynecol 2007;109(2, Part 1):262–9.
[26] Tahseen S, Griffiths M. Vaginal birth after two caesarean sections (VBAC-2)-a systematic review with meta-analysis of success rate and adverse outcomes of VBAC-2 versus VBAC-1 and repeat (third) caesarean sections. BJOG An Int J Obstet Gynaecol 2009;117(1):5–19.
[27] Bujold E, Jastrow N, Simoneau J, Brunet S, Gauthier R. Prediction of complete uterine rupture by sonographic evaluation of the lower uterine segment. Am J Obstet Gynecol 2009;201(3):320.e1–6.
[28] Donnez O, Donnez J, Orellana R, Dolmans M. Gynecological and obstetrical outcomes after laparoscopic repair of a cesarean scar defect in a series of 38 women. Obstet Gynecol Surv 2017;72(5):283–4.
[29] Osser O, Valentin L. Clinical importance of appearance of cesarean hysterotomy scar at transvaginal ultrasonography in nonpregnant women. Obstet Gynecol 2011;117(6):1438–9.
[30] Gubbini G, Centini G, Nascetti D, Marra E, Moncini I, Bruni L, et al. Surgical hysteroscopic treatment of cesarean-induced isthmocele in restoring fertility: prospective study. J Minim Invasive Gynecol 2011;18(2):234–7.
[31] Bij de Vaate A, Brölmann H, van der Voet L, van der Slikke J, Veersema S, Huirne J. Ultrasound evaluation of the Cesarean scar: relation between a niche and postmenstrual spotting. Ultrasound Obstet Gynecol 2010;37(1):93–9.
[32] Wang C, Chiu W, Lee C, Sun Y, Lin Y, Tseng C. Cesarean scar defect: correlation between Cesarean section number, defect size, clinical symptoms and uterine position. Ultrasound Obstet Gynecol 2009;34(1):85–9.
[33] Thisted D, Mortensen L, Hvidman L, Krebs L. Operative technique at caesarean delivery and risk of complete uterine rupture in a subsequent trial of labour at term. A registry case-control study. PLoS One 2017;12(11):e0187850.
[34] Babu K, Magon N. Uterine closure in cesarean delivery: a new technique. N Am J Med Sci 2012;4(8):358.
[35] Demers S, Roberge S, Afiuni Y, Chaillet N, Girard I, Bujold E. Survey on uterine closure and other techniques for caesarean section among Quebec's Obstetrician-gynaecologists. J Obstet Gynaecol Can 2013;35(4):329–33.
[36] Bujold E, Gauthier R. The role of uterine closure in the risk of uterine rupture. Obstet Gynecol 2010;116(4):995–6.
[37] Glavind J, Madsen L, Uldbjerg N, Dueholm M. Ultrasound evaluation of Cesarean scar after single- and double-layer uterotomy closure: a cohort study. Ultrasound Obstet Gynecol 2013;42(2):207–12.
[38] Hudic I, Bujold E, Fatusic Z, Roberge S, Mandzic A, Fatusic J. Risk of uterine rupture following locked vs unlocked single-layer closure. Med Arch 2012;66(6):412.
[39] Ceci O, Cantatore C, Scioscia M, Nardelli C, Ravi M, Vimercati A, et al. Ultrasonographic and hysteroscopic outcomes of uterine scar healing after cesarean section: comparison of two types of single-layer suture. J Obstet Gynaecol Res 2012;38(11):1302–7.
[40] Caesarean section surgical techniques (CORONIS): a fractional, factorial, unmasked, randomised controlled trial. Lancet 2013;382(9888):234–48.
[41] Yasmin S, Sadaf J, Fatima N. Impact of methods for uterine incision closure on repeat caesarean section scar of lower uterine segment [cited 4 November 2018] J Coll Phys Surg Pakistan [Internet] 2011;21(9):522–6. Available from: https://www.ncbi.nlm.nih.gov/pubmed/21914406.
[42] Roberge S, Bujold E. 685: single versus double layer closure and risk of uterine rupture : systematic review and meta-analysis. Am J Obstet Gynecol 2009;201(6):S247.
[43] Roberge S, Chaillet N, Boutin A, Brassard N, Gauthier R, Moore L, et al. 684: locked vs unlocked sutures for uterine closure and the risk of uterine rupture. Am J Obstet Gynecol 2011;204(1):S270.
[44] Defline A, Schmitz T, Sentilhes L, Raiffort C, Goffinet F, Raquin C, et al. 596: risk factors for uterine rupture in trial of labor after cesarean: a multicenter case-control study. Am J Obstet Gynecol 2014;210(1):S293–4.
[45] Vachon-Marceau C, Demers S, Bujold E, Roberge S, Gauthier R, Pasquier J, et al. Single versus double-layer uterine closure at cesarean: impact on lower uterine segment thickness at next pregnancy. Am J Obstet Gynecol 2017;217(1):65.e1–5.

[46] Hudic I, Fatušic Z, Kameric L, Mišic M, ŠERAK I, Latifagic A. Vaginal delivery after Misgav–Ladach cesarean section – is the risk of uterine rupture acceptable? J Matern Fetal Neonatal Med 2010;23(10):1156–9.
[47] Tanimura S, Funamoto H, Hosono T, Shitano Y, Nakashima M, Ametani Y, et al. New diagnostic criteria and operative strategy for cesarean scar syndrome: endoscopic repair for secondary infertility caused by cesarean scar defect. J Obstet Gynaecol Res 2015;41(9):1363–9.
[48] Vervoort A, Vissers J, Hehenkamp W, Brölmann H, Huirne J. The effect of laparoscopic resection of large niches in the uterine caesarean scar on symptoms, ultrasound findings and quality of life: a prospective cohort study. BJOG An Int J Obstet Gynaecol 2017;125(3):317–25.
[49] Pomorski M, Fuchs T, Rosner-Tenerowicz A, Zimmer M. Sonographic evaluation of surgical repair of uterine cesarean scar defects. J Clin Ultrasound 2017;45(8):455–60.
[50] Dosedla E, Calda P. Outcomes of laparoscopic treatment in women with cesarean scar syndrome. Med Sci Mon Int Med J Exp Clin Res 2017;23:4061–6.
[51] Marotta M, Donnez J, Squifflet J, Jadoul P, Darii N, Donnez O. Laparoscopic repair of post-cesarean section uterine scar defects diagnosed in nonpregnant women. J Minim Invasive Gynecol 2013;20(3):386–91.
[52] Chang Y, Tsai E, Long C, Lee C, Kay N. Resectoscopic treatment combined with sonohysterographic evaluation of women with postmenstrual bleeding as a result of previous cesarean delivery scar defects. Am J Obstet Gynecol 2009;200(4):370.e1–4.
[53] Jeremy B, Bonneau C, Guillo E, Paniel B, Le Tohic A, Haddad B, et al. Hernie transmurale isthmique de l'utérus : résultats de l'isthmorraphie sur la symptomatologie et la fertilité. Gynecol Obstet Fertil 2013;41(10):588–96.
[54] Poloni G, Busato E. O551 vaginal birth after two cesarean sections (VBAC - 2): a review of success rate and adverse outcomes in our experience. Int J Gynecol Obstet 2012;119:S455.
[55] Tinelli A, Hurst B, Mettler L, Tsin D, Pellegrino M, Nicolardi G, et al. Ultrasound evaluation of uterine healing after laparoscopic intracapsular myomectomy: an observational study. Hum Reprod 2012;27(9):2664–70.
[56] Tepper R, Beyth Y, Klein Z, Aviram R. Postmyomectomy sonographic imaging: uterus remodeling and scar repair. Arch Gynecol Obstet 2009;280(3):509–11.
[57] Nabhan A. Long-term outcomes of two different surgical techniques for cesarean. Int J Gynecol Obstet 2007;100(1):69–75.
[58] [cited 4 November 2018] Birth after previous caesarean birth [Internet]. Rcog.org.uk. 2018. Available from: https://www.rcog.org.uk/globalassets/documents/guidelines/gtg_45.pdf.
[59] Practice bulletin No. 184. Obstetrics & gynecology. ACOG 2017;130(5):e217–33.
[60] [cited 4 November 2018] Guidelines for vaginal birth after previous caesarean birth [Internet]. Sogc.org. 2018. Available from: https://sogc.org/wp-content/uploads/2013/01/155E-CPG-February2005.pdf.
[61] Bamberg C, Hinkson L, Dudenhausen J, Bujak V, Kalache K, Henrich W. Longitudinal transvaginal ultrasound evaluation of cesarean scar niche incidence and depth in the first two years after single- or double- layer uterotomy closure: a randomized controlled trial. Acta Obstet Gynecol Scand 2017;96(12):1484–9.
[62] van der Voet L, Bij de Vaate A, Veersema S, Brölmann H, Huirne J. Long-term complications of caesarean section. The niche in the scar: a prospective cohort study on niche prevalence and its relation to abnormal uterine bleeding. BJOG An Int J Obstet Gynaecol 2014;121(2):236–44.
[63] van der Voet L, Limperg T, Veersema S, Timmermans A, Bij de Vaate A, Brölmann H, et al. Niches after cesarean section in a population seeking hysteroscopic sterilization. Eur J Obstet Gynecol Reprod Biol 2017;214:104–8.
[64] Feng Y, Li M, Liang X, Li X. Hysteroscopic treatment of postcesarean scar defect. J Minim Invasive Gynecol 2012;19(4):498–502.
[65] Li C, Tang S, Gao X, Lin W, Han D, Zhai J, et al. Efficacy of combined laparoscopic and hysteroscopic repair of post-cesarean section uterine diverticulum: a retrospective analysis. BioMed Res Int 2016;2016:1–6.
[66] Fabres C, Aviles G, De La Jara C, Escalona J, Muñoz J, Mackenna A, et al. The cesarean delivery scar pouch. J Ultrasound Med 2003;22(7):695–700.
[67] Gubbini G, Casadio P, Marra E. Resectoscopic correction of the "isthmocele" in women with postmenstrual abnormal uterine bleeding and secondary infertility. J Minim Invasive Gynecol 2008;15(2):172–5.
[68] Vervoort A, van der Voet L, Hehenkamp W, Thurkow A, van Kesteren P, Quartero H, et al. Hysteroscopic resection of a uterine caesarean scar defect (niche) in women with postmenstrual spotting: a randomised controlled trial. BJOG An Int J Obstet Gynaecol 2017;125(3):326–34.
[69] Tanos V, Berry K. Benign and malignant pathology of the uterus. Best Pract Res Clin Obstet Gynaecol 2018;46:12–30.
[70] Paul P, Koshy A, Thomas T. Pregnancy outcomes following laparoscopic myomectomy and single-layer myometrial closure. Hum Reprod 2006;21(12):3278–81.
[71] Tentas I. Uterine rupture following laparoscopic myomectomy: an Overview. Int J Gynecol Obstet 2017;6(4).
[72] Ota Y, Andou M, Kanao H, Takagi Y, Hada T. Convex lens resection method is an effective strategy for laparoscopic adenomyomectomy. J Minim Invasive Gynecol 2008;15(6):17S–8S.
[73] Osada H, Silber S, Kakinuma T, Nagaishi M, Kato K, Kato O. Surgical procedure to conserve the uterus for future pregnancy in patients suffering from massive adenomyosis. Reprod Biomed Online 2011;22(1):94–9.
[74] Osada H. Uterine adenomyosis and adenomyoma: the surgical approach. Fertil Steril 2018;109(3):406–17.
[75] Osada H, Nagaishi M, Teramoto S. Adenomyomectomy by uterine muscle flap method: clinical outcome and investigation of the preventive effect on uterine rupture. Obstet Gynecol 2017;84:1303–15.
[76] Kitade M, Kumakiri K, Kuroda J, Jinushi M, Ujihira Y, Ikuma K, et al. Is laparoscopic uterine preservation surgery effective against infertility associated with uterine adenomyosis? A study of perinatal prognosis by postoperative pregnancy rate and the presence of prior surgery. J Jpn Sociol Endometr 2017;38:70.
[77] Parker W, Einarsson J, Istre O, Dubuisson J. Risk factors for uterine rupture after laparoscopic myomectomy. J Minim Invasive Gynecol 2010;17(5):551–4.
[78] Pollio F, Staibano S, Mascolo M, Salvatore G, Persico F, De Falco M, et al. Uterine dehiscence in term pregnant patients with one previous cesarean delivery: Growth factor immunoexpression and collagen content in the scarred lower uterine segment. Am J Obstet Gynecol 2006;194(2):527–34.

[79] Kim H, Oh S, Choi S, Park H, Cho G, Chung J, et al. Uterine rupture in pregnancies following myomectomy: a multicenter case series. Obstet Gynecol Sci 2016;59(6):454.
[80] Bujold E, Mehta S, Bujold C, Gauthier R. Interdelivery interval and uterine rupture. Am J Obstet Gynecol 2002;187(5):1199–202.
[81] Nezhat C, Li A, Abed S, Balassiano E, Soliemannjad R, Nezhat A, et al. Strong Association Between Endometriosis and Symptomatic Leiomyomas. J Soc Laparoendosc Surg–J Soc Laparoendosc Surg 2016;20(3):00053. e2016.
[82] Werner S, Grose R. Regulation of wound healing by Growth factors and cytokines. Physiol Rev 2003;83(3):835–70.
[83] Bhafarnejad M, Akrami M, Davari-Tanha F, Adabi K, Nekuie S. Vasopressin effect on operation time and frequency of electrocauterization during laparoscopic stripping of ovarian endometriomas: a randomized controlled clinical trial. J Reproduction Infertil 2014;15:199–204.
[84] Saeki A, Matsumoto T, Ikuma K, Tanase Y, Inaba F, Oku H, et al. The vasopressin injection technique for laparoscopic excision of ovarian endometrioma: a technique to reduce the use of coagulation. J Minim Invasive Gynecol 2010;17(2):176–9.
[85] Fujimoto A, Morimoto C, Hosokawa Y, Hasegawa A. Suturing method as a factor for uterine vascularity after laparoscopic myomectomy. Eur J Obstet Gynecol Reprod Biol 2017;211:146–9.
[86] El-Agwany A. Conservative management of infected postpartum uterine dehiscence after cesarean section. J Med Ultrasound 2018;26(1):59.