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Research Article

How does uterine contractile activity affect the success of trial of labour after caesarean section, and the risk of uterine rupture? An exploratory, blinded analysis of a cohort from a randomised controlled trial

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Objective To investigate the impact of uterine contractile activity on the outcome of trial of labour after caesarean section (TOLAC).

Design Secondary, blinded analyses of a prospective TOLAC cohort.

Setting Two labour wards, one in a university tertiary hospital and the other in a central hospital.

Population A total of 194 TOLAC parturients with intrauterine tocodynamometry during labour.

Methods Analysis of intrauterine pressure, frequency of contractions and baseline tonus of uterine muscle in 30-minute periods for 4 hours before birth.

Main outcome measures Primary outcome: uterine contractile activity during TOLAC. Secondary aims: contributors associated with failed TOLAC and uterine rupture.

Results TOLAC succeeded in 74% of cases. Uterine contractile activity, expressed as intrauterine pressure, was significantly higher in successful TOLAC compared with failed TOLAC (210 versus 170 Montevideo units). The statistically significant risk factors of failed TOLAC, after multivariate regression analysis, were prolonged gestational age, reduced cervical dilatation at admission and lower mean intrauterine pressure. In cases of uterine rupture, contractile activity did not differ from that in failed TOLAC. Cervical ripening with a Foley catheter appeared to be a risk factor for uterine rupture, as well as cervical dilatation <3 cm at admission. The incidence of total uterine rupture was 2.6% (n = 5).

Conclusions Women with successful vaginal birth had higher uterine contractile activity than those experiencing failed TOLAC or uterine rupture despite similar use of oxytocin. Induction of labour with a Foley catheter turned out to be a risk factor for uterine rupture during TOLAC among parturients with no previous vaginal delivery.

Keywords Contractions, intrauterine pressure catheter, Montevideo unit, tocodynamometry, trial of labour after caesarean section, uterine rupture, vaginal birth after caesarean section.

Tweetable abstract During VBAC the response to oxytocin, assessed as intrauterine pressure, is greater and adequate, in contrast to failed TOLAC.

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Introduction

While the number of caesarean sections (CS) has risen worldwide, the number of pregnant women with uterine scars has risen concomitantly. The prevalence of trial of labour after caesarean section (TOLAC) varies between countries, being partly influenced by financial issues[1] and fear of medical litigation considering the risk of its major

complication, uterine rupture (UR).[2] Therefore, the rates of vaginal birth after CS (VBAC) show great variation between countries,[2] being 9% in 2006 in the USA, for example,[3] and 55% in Finland between 2016 and 2018 (THL, Finnish Institute for Health and Welfare, Medical Birth Register).

TOLAC is successful in 63–86% of cases,[2,4–6] but UR is a major complication associated with it. The risk of complete UR during trial of labour after a single CS is estimated to be 0.2–0.8%, and after two or more it is up to 1.8%,[2,3] but higher rates (2.4–4.7%) have also been reported among TOLAC populations with induction of labour.[5,7] The risk of maternal morbidity is dependent on the success of TOLAC.[8–10] However, repeated CS is associated with increased long-term maternal morbidity,[8,11] and CS may also influence long-term morbidity of offspring in terms of risks of obesity, asthma, food allergy and eczema.[1,8,12]

Uterine contractile activity can be expressed as the frequency of contractions, intrauterine pressure (IUP), reflecting the power of contractions, and the basal tonus of uterine muscle. According to former guidelines,[13] IUP should be over 200 Montevideo units (MVU) during augmented labour in order to achieve vaginal birth. In labours ending in UR, tachysystole, i.e. more than five contractions/10 minutes, or changes in basal tonus have been reported, but these effects are not always found in cases of UR.[14]

There are controversial opinions on the usefulness of intrauterine tocodynamometry (IT) to predict UR during TOLAC,[4,14,15] and only a few studies have been focused solely on contractions in cases of UR.[14,16,17] Even fewer studies have involved IUP in assessing the success of TOLAC.[17–19] Our randomised controlled trial comparing IT with external tocodynamometry, including TOLAC parturients for the first time, has been published earlier.[20] In that study, the benefit of IT during TOLAC was in the reduction of oxytocin dosage, but IT did not improve the success of TOLAC or protect women from UR.

We performed an exploratory analysis of our randomised controlled trial data, concerning the TOLAC with IT subpopulation, considering the influence of uterine contractile activity on the outcome of TOLAC and the risk of UR. We also studied all cases of UR in our material to investigate predictive signs of rupture, and contributors to it.

Methods

The study population consisted of 194 parturients undergoing TOLAC with IT monitoring for at least 1 hour before birth who participated in our previously published randomised trial.[20] In the original randomised controlled trial conducted in 2012–17 we randomised a total of 1504 parturients to undergo either IT or external tocodynamometry during labour. One of the subgroups recruited consisted of TOLAC parturients (n = 269), of whom 132 were allocated to the IT subgroup although three of them did not undergo it. Changes in the monitoring group took place for medical reasons, and 65 TOLAC parturients in the external tocodynamometry group underwent IT during labour, i.e. a total of 194 TOLAC parturients were monitored by IT during labour. Parturients with either one or two (n = 2) previous CS, with singleton pregnancies with the fetus in cephalic position, gestational age ≥37 weeks and cervical dilatation ≤7 cm were recruited, and recruitment took place at the time of the first vaginal examination in the labour room. Both spontaneous-onset and induced labours were accepted, the induction methods involving misoprostol (maximum dose 150 μg/day) or balloon catheter (Rusch™ Foley catheter with 50–60 ml saline filling) ripening, or amniotomy and/or oxytocin, if the cervix was sufficiently ripe for those methods. In all cases vaginal birth was considered to be possible.

Cardiotocograms (CTG) were monitored using Philips Avalon FM30 or FM50 Gemini equipment (Koninklijke Philips N.V., Amsterdam, the Netherlands) and IUP catheters were sensor-tipped (Koala, Clinical Innovations, Murray, UT, USA).

Data on the parturients and neonates were collected from medical records and research records of the study. Two investigators interpreted 194 intrauterine tocograms blinded, i.e. without knowing maternal or neonatal characteristics nor the outcome of TOLAC. Further, the following tocodynamometric measurements were analysed: uterine contractile power expressed as MVU, basal intrauterine pressure (mmHg) and frequency of contractions/10 minutes. In addition, cervical dilatation and oxytocin doses at 4 hours, 3 hours, 2 hours, and 1 hour before birth, and immediately before birth, were recorded. Regardless of the indication for CS, '1 hour before birth' measures were analysed at the time of CS decision. Montevideo units were calculated in 30-minute periods (15 minutes before and after exact times, i.e. 3.25–2.75 hours before labour, etc.). Montevideo units were defined as the sum of peak amplitudes (mmHg) above baseline uterine tonus in all contractions for 10-minute periods. All UR were found at laparotomy (CS or postpartum), and they were defined as total if all layers of the uterine muscle were ruptured, and incomplete if the uterine serosa were still intact. Oxytocin administration followed hospital guidelines, i.e. modified active management of labour protocol, and the maximum oxytocin dose recommended was 15 mIU/min. Augmentation began 1 hour after amniotomy (if carried out) and midwives increased the doses by 2.0–2.5 mIU/min every 20–30 minutes until progression of labour was adequate or 150–300 MVU were reached.

To find out how uterine contractile activity (among other obstetric contributors) affected the success of TOLAC

and the risk of UR, we made two comparisons. Women with VBAC – including vacuum extractions – were compared with parturients who underwent repeat CS. We also compared labours with complete or incomplete UR with other TOLAC labours.

Outcome measures

The primary outcome was uterine contractile activity expressed as IUP, frequency of contractions and basal tone of uterine muscle. Secondary outcomes included use of oxytocin during labour, and contributors associating with failed TOLAC or UR.

Relevant core outcome sets did not exist at the time of designing this study, and still do not exist, or are currently under development.

Statistical analyses

All statistical analyses were performed using SPSS for Windows 26.0 (IBM SPSS Statistics for Windows, Version 26.0: IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means with standard deviations, or medians with interquartile range (IQR), depending on the shape of the distribution. Categorical variables were expressed as frequencies and percentages. The Mann–Whitney *U* test, the Kruskall–Wallis test, Fisher's exact test, the chi-square test and logistic regression analysis were used as appropriate. Analysis of the data shown in Figure 1(A–C) was carried out by means of variance analysis of repeated measures. The results of logistic regression analyses were expressed in terms of odds ratios (OR) (univariate analysis) and adjusted ORs (multivariable analysis) and 95% confidence intervals (95% CIs). A *P*-value less than 0.05 was considered statistically significant. All *P* values are two-sided.

Patient and public involvement

Patients were not involved in the development of the research. The results of the study will be disseminated among professionals but not directly to study participants.

Results

We analysed a total of 194 TOLAC labours and tocograms. The success rate of vaginal birth, including 30 vacuum extractions, was 74% (n = 144). Indications for current CS were mainly dystocia (n = 22; 44%); 11 were carried out because of fetal distress (22%), ten because of a combination of dystocia and fetal distress (20%); there were six cases of suspicion of rupture (12%), and one indication was not clearly identified. The mean degree of cervical dilatation at the moment of deciding on CS was 5.4 cm (SD 2.5 cm).

Maternal and neonatal background and outcomes, and intrapartum factors of successful VBAC and failed TOLAC are presented in Table 1. If there had been one or more previous vaginal deliveries, the success rate of TOLAC was 90%, whereas those with no previous vaginal deliveries had a success rate of 72%. Advanced gestational age, an unripe cervix at recruitment and chorioamnionitis during labour as well as a raised neonatal birthweight predisposed women to failed TOLAC. Although pre-pregnancy body mass indices did not differ significantly between outcome groups, a body mass index of 35 kg/m^2 or more was associated with only 39% of the parturients with vaginal delivery (VD), in contrast to leaner women (77%); OR for failed TOLAC 5.30 (95% CI 1.64–17.05; P = 0.005).

Table 2 shows the use of oxytocin and uterine contractile activity during labour in relation to the success of TOLAC. There was no difference in the use of oxytocin between groups, but IUP during the last 4 hours before birth was greater in the VBAC group compared with the failed TOLAC group. Likewise, the proportion of those achieving IUP of at least 200 MVU was greater among those with VBAC than those with failed TOLAC.

Figure 1(A–C) illustrates the trends of IUP, doses of oxytocin and cervical dilatation during the progress of labour in the last 4 hours before birth, hour by hour. In successful VBAC, the IUP rose progressively toward birth, in contrast to failed TOLAC.

Among the VBAC group, the parturients without previous VD had higher maximum IUP than those who had had VD in the past (IUP during 4 hours before birth, median 220 MVU, IQR 177–271, versus 172 MVU, IQR 100–228; P = 0.007), but if TOLAC failed, there was no significant difference in IUP according to history.

Univariate analyses of maternal background and intrapartum factors affecting the success of TOLAC are presented in Tables 1 and 2. In multivariable analysis of significant variables known before or during labour an increase of mean IUP by 10 MVU was associated with successful TOLAC (aOR 1.12, 95% CI 1.04–1.20), as was wider dilatation of the cervix at recruitment (aOR 1.45, 1.06–2.00) for every centimetre increase. Prolonged gestational age was associated with failed TOLAC (aOR 1.05, 1.01–1.10) for every additional day. Neonatal outcome measures were not included in the multivariable analysis because they are known only after labour. However, in univariate analysis, higher birthweight and low 5-minute Apgar scores at 5 minutes were more frequent if TOLAC failed.

The rate of total UR was 2.6% (n = 5) and the rate of incomplete UR with considerable symptoms (such as abnormal abdominal pain, fetal distress in CTG) was 1.5% (n = 3). Table 3 presents maternal background and prelabour factors in labours complicated by UR compared with other TOLACs. Induction of labour in cases of an unfavourable cervix, i.e. cervical ripening with a Foley catheter and/or prostaglandins, increased the risk of UR significantly, but

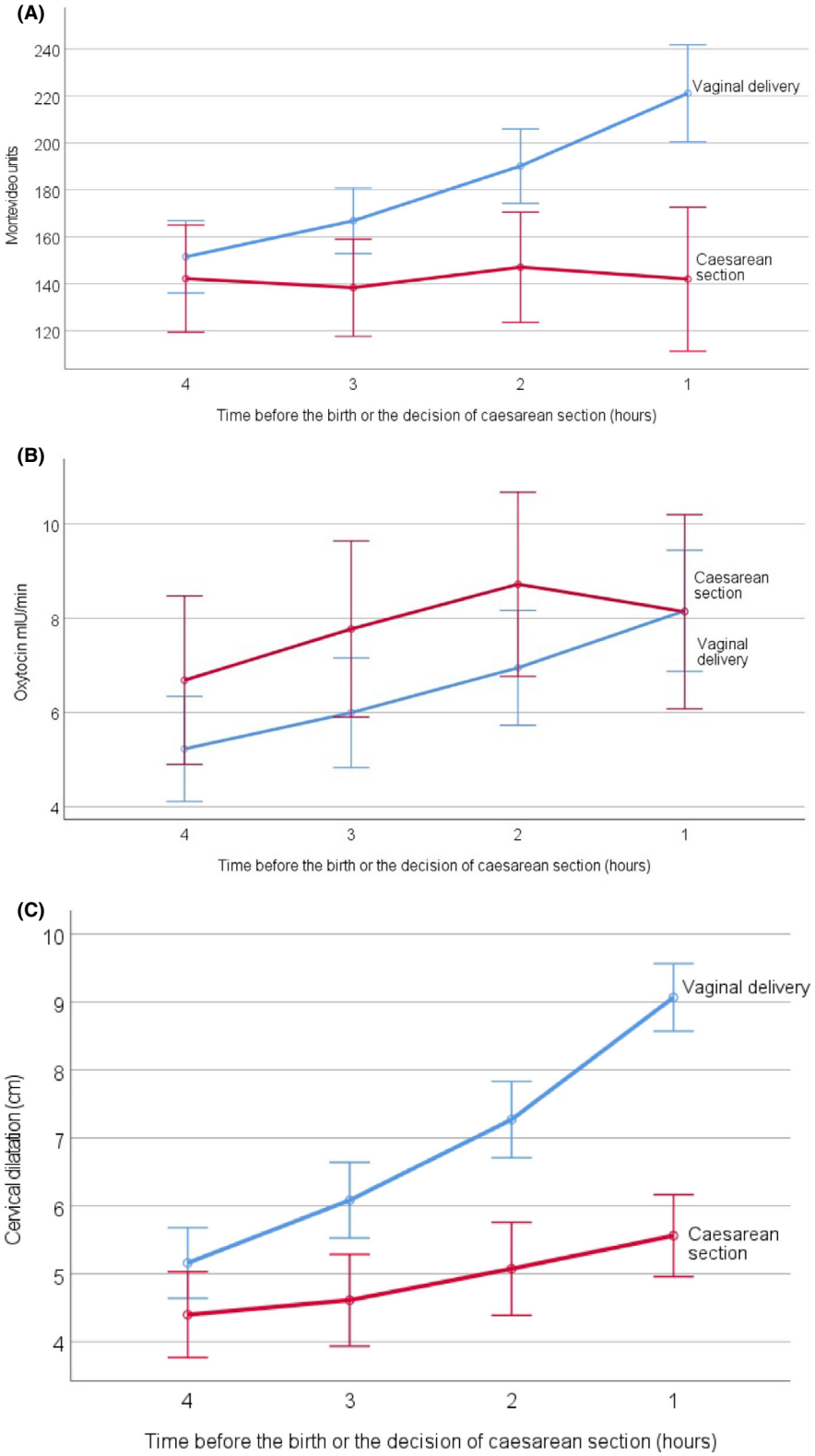

Figure 1. (A) Intrauterine pressure in Montevideo units at different time-points before birth according to the success of TOLAC. (B) Use of oxytocin during the last 4 hours before vaginal birth or the decision on caesarean section. (C) Cervical dilatation during the last 4 hours before vaginal birth or the decision on caesarean section.

Table 1. Maternal background and intrapartum factors and their association with failure of TOLAC

	VBAC (*n* = 144)		Failed TOLAC (*n* = 50)		Univariate analysis		
	n/mean/median	%/SD/IQQ	*n*/mean/median	%/SD/IQR	OR	95% CI	*P* value
Gestational age (days)	278.0	8.8	281.8	8.9	1.05	1.01–1.09	0.011
Maternal age (years)	31.5	4.7	31.3	5.2	0.99	0.93–1.06	0.840
Maternal height (cm)	165.0	5.8	163.5	4.4	0.95	0.89–1.01	0.091
Prepregnancy BMI (kg/m^2)	26.0	5.0	27.5	7.0	1.05	0.99–1.11	0.111
Any diabetes	40	28%	17	34%	1.34	0.67–2.67	0.405
Interval between CS and this delivery (years)	3.0	2.0–5.0	3.0	2.0–4.0	0.96	0.85–1.08	0.489
No previous vaginal delivery	118	82%	47	94%	3.45	1.00–11.9	0.039
Previous CS							
Elective CS	37	26%	14	28%	1.12	0.55–2.32	0.750
Acute CS*	107	74%	36	72%	0.89	0.43–1.83	
"Cold" CS i.e., no contractions, or cervical dilatation ≤1 cm	63	44%	22	44%	1.01	0.53–1.93	0.976
Cervical dilatation <6 cm at CS decision	105	73%	42	84%	1.96	0.84–4.54	0.119
Current labour, i.e. TOLAC							
Induction of labour by	86	60%	29	58%	0.93	0.49–1.79	0.831
Prostaglandins or Foley catheter	38	26%	16	32%	1.31	0.65–2.64	0.446
Amniotomy or/and oxytocin	48	33%	13	26%	0.70	0.34–1.45	0.336
Cervical dilatation at recruitment (cm)	3.6	1.4	3.0	1.3	0.71	0.54–0.93	0.012
Epidural analgesia	132	92%	44	88%	0.67	0.24–1.88	0.412
Chorioamnionitis	11	7.6%	10	20.0%	3.02	1.20–7.63	0.019
Postpartum haemorrhage (ml)	450	330–550	650	450–1100	1.13**	1.04–1.22	<0.001
Neonatal outcome							
Birth weight (kg)	3.7	0.5	3.9	0.5	1.11***	1.04–1.20	0.004
Birth weight ≥4 kg	35	24	21	42	2.26	1.14–4.45	0.017
Composite neonate adverse outcome	13	9%	8	16%	1.92	0.75–4.95	0.177
Admission to NICU****	12	8%	6	12%	1.50	0.53–4.23	0.412
Umbilical artery pH <7.05	0	0%	1	2%	1.02	0.98–1.06	0.258
Apgar score <7 at 5 min	2	1.4%	4	8.0%	6.17	1.10–34.8	0.039

Maternal and neonatal outcomes of TOLAC.
BMI, body mass index; NICU, neonatal intensive care unit; SD, standard deviation.
*Any unplanned caesarean section performed during trial of vaginal labour.
**OR counted per 100 ml.
***OR counted per 100 g.
****Admission to NICU; umbilical artery pH <7.05 or/and Apgar score <7 at 5 min.

induction by means of amniotomy and/or oxytocin was not a risk factor for UR. When we compared spontaneous labours with labours in which a Foley catheter was used, the odds ratio for UR was 6.60 (95% CI 1.27–34.35; $P = 0.019$). Cervical dilatation at recruitment was less pronounced among UR parturients than in the other women.

Uterine contractile activity and the use of oxytocin in UR cases did not differ when compared with other TOLACs (Table 4). However, the maximum IUP was lower among UR cases when compared with VBAC cases ($P = 0.046$) but did not differ significantly from that in failed TOLAC ($P = 0.416$) (values in Tables 2 and 4).

A descriptive analysis of UR cases is presented in Table S1. None of these eight parturients had had previous VD. One delivery was accomplished by vacuum extraction and the rupture was recognised after birth, whereas all the others underwent CS. One of the cases necessitated hysterectomy and embolisation. Only one neonate needed treatment in a neonatal intensive care unit. In two cases, abnormal CTG results were seen immediately after placement of an IUP catheter, and in the other cases the interval between IUP catheter placement and rupture ranged from 3 to 10 hours. Four of the eight UR parturients experienced tachysystole during labour; there were seven cases of abnormal fetal heart rate in CTG and three cases of total cessation of measurable contractions. CTGs of rupture cases are presented as Supplementary material (Figures S1–S8).

Table 2. Use of oxytocin and uterine contractile activity during labour and their association with failure of TOLAC

	VBAC (*n* = 144)		Failed TOLAC (*n* = 50)		Univariate analysis		
	n/mean/median	%/SD/IQR	*n*/mean/median	%/SD/IQR	OR	95% CI	*P*-value
Oxytocin augmentation in stage I	133	92	44	88	0.61	0.21–1.74	0.386
Oxytocin total consumption, IU	3.0	1.0–5.0	3.0	0.65–5.58	0.99	0.90–1.08	0.774
During four hours before birth							
Oxytocin maximum dose, mIU/min	10.0	7.5–15.0	12.5	5.0–15.0	1.02	0.98–1.07	0.328
Oxytocin mean dose, mIU/min	5.0	1.8–10.6	6.9	1.5–12.5	1.02	0.97–1.07	0.509
IUP mean, MVUs	167	124–203	132	102–177	0.93*	0.87–0.98	0.009
IUP maximum, MVUs	210	170–270	170	122–220	0.96*	0.92–1.00	0.028
IUP maximum < 200 MVUs	55	38	31	62	2.63	1.35–5.00	0.004
Frequency of contractions/10 min, maximum	4.7	4.0–5.0	4.3	4.0–5.0	0.89	0.66–1.19	0.428
Tachysystole	48	33	11	22	0.56	0.27–1.20	0.133
Uterine muscle basal tonus maximum, mmHg	20	20–25	20	15–21	0.99	0.95–1.03	0.562
During stage II of labour							
Final oxytocin dose, mIU/min	10.0	5.0–15.0	17.1 (*n* = 2)				
IUP, MVUs**	355	250–420	120 (*n* = 1)				
Frequency of contractions/10 min	5.0	5.0–6.0	4.0 (*n* = 1)				
Uterine muscle basal tonus maximum, mmHg**	20	15–27	20 (*n* = 1)				

NICU, neonatal intensive care unit; SD, standard deviation.
*OR counted per 10 MVUs.
**74 missing values when IUPC was taken out or it slid out.

Discussion

Main findings

The success of TOLAC, 74% in our study population, was comparable with previously reported rates. [2,3] The contributing factors associated with failed TOLAC were similar to those in previous studies: no previous VD, admission to a labour ward at an early stage of labour and prolonged gestation, which may carry a risk of intrapartum CS.[3,21–23] In contrast to earlier studies,[22,23] the indication of previous CS did not influence the success of TOLAC in our study population.

There are only a few reports concerning intrauterine pressure during TOLAC, and in contrast to earlier studies concerning IUP and TOLAC,[17,18] we found significantly lower IUP in failed TOLAC compared with VBAC. As the dosages of oxytocin tended to be higher among failed TOLACs, it seems that raising the oxytocin dosage does not necessarily improve uterine contractile activity in this group (Figures 1A,B), in contrast to VBAC, where the dosages of oxytocin and the uterine response (as IUP) were correlated. Deficient IUP in response to oxytocin therapy and the lack of correlation between oxytocin dosage and IUP among cases of failed TOLAC suggest that the effects of oxytocin on uterine function are different in labours complicated by dystocia compared with normal labour. This difference could partly be explained by differences in labour stage despite similar cervical status at 4 hours before birth or at the time of deciding on CS. Probably there are as yet unknown factors mediating the action of oxytocin on the uterus in labour.

Our result of lower IUP among TOLAC parturients having had a previous VD confirms the finding reported by Arulkumaran et al.[19] It seems that parous women do not need as high an IUP as nulliparas to achieve VD, and previous full dilatation of the cervix reduces the uterine muscle forces needed for giving birth in subsequent labour.

In our study, IUP was significantly lower in UR cases than during successful VBAC, which is in contrast to the results of some earlier studies.[4,17] This finding is partly explained by the wide range of IUP among UR cases (Table S1). On the other hand, IUP in UR cases was not different from that in the total TOLAC group. The tocographic features preceding UR that have been described in earlier studies[14,24] were found in only some of our cases. On the basis of the results of former studies[4,5,14,16] and those of the present study, it seems that there are no typical contractility patterns repeatedly seen when UR occurs. Labour-ward staff have to be aware of the risk of UR during every TOLAC.

Table 3. Maternal background and prelabour factors and their association with the risk of uterine rupture

	Uterine rupture (*n* = 8)		Other TOLAC (*n* = 186)		Univariate analysis		
	n/mean/median	%/SD/IQR	*n*/mean/median	%/SD/IQR	OR	95% CI	*P* value
Gestational age (days)	284.3	8.8	278.8	8.9	1.08	0.99–1.19	0.099
Maternal age (years)	33.3	4.9	31.4	4.8	1.09	0.93–1.27	0.279
Maternal height (cm)	162	3.6	165	5.6	0.92	0.80–1.05	0.207
Prepregnancy BMI (kg/m^2)	25.7	6.1	26.4	5.6	0.98	0.85–1.12	0.734
Diabetes, any type	3	38%	54	29%	1.47	0.34–6.35	0.609
No previous vaginal deliveries	8	100%	157	84%	1.05	1.01–1.09	0.608
Induction of labour by	6	75%	109	59%	2.12	0.42–10.78	0.365
FC and/or PG	6	75%	48	26%	8.63	1.68–44.18	0.010
Foley catheter only	4	50%	24	13%	6.75	1.58–28.80	0.010
Prostaglandins only	0	0%	13	7.0%	0.96	0.93–0.99	1.000
FC after/followed by PG	2	25%	11	5.9%	5.30	0.96–29.4	0.056
Foley catheter alone or after/followed by PG	6	75%	35	19%	12.94	2.51–66.86	0.001
Amniotomy and/or oxytocin	0	0%	61	33%	0.94	0.90–0.98	0.058
Cervix dilatation <3 cm at recruitment	5	63%	45	24%	5.26	1.20–25.0	0.028
Previous CS features							
Interval between CS and this delivery (years)	3.0	2.3–3.8	3.0	2.0–5.0	0.85	0.59–1.22	0.380
One-layer uterine wound closure in previous CS	1	13%	18	10%	1.33	0.16–11.5	0.793
Cervical dilatation ≥6 cm before previous CS	1	13%	46	25%	0.44	0.05–3.63	0.442

BMI, body mass index; FC, Foley catheter; PG, prostaglandin; SD, standard deviation.

Table 4. Use of oxytocin and uterine contractile activity during labour and their association with the risk of uterine rupture

	Uterine rupture (*n* = 8)		Other TOLAC (*n* = 186)		Univariate analysis		
	n/mean/median	%/SD/IQR	*n*/mean/median	%/SD/IQR	OR	95% CI	*P* value
Failed TOLAC, i.e. caesarean section	7	88%	43	23%	23.3	2.79–195	<0.001
Oxytocin augmentation in the first stage	8	100%	169	91%	1.05	1.01–1.08	1.000
Oxytocin total consumption (IU)	1.2	0.3–2.8	3.0	1.0–5.0	0.80	0.57–1.12	0.189
Postpartum hemorrhage (ml)	1350	430–2800	450	300–600	4.66***	1.96–11.1	0.022
During 4 hours before birth							
Oxytocin mean dose (mIU/min)	2.6	0.8–10.6	5.7	1.9–10.8	0.95	0.83–1.08	0.421
Oxytocin maximum dose (mIU/min)	7.8	3.1–14.4	10.0	7.5–15.0	0.98	0.88–1.10	0.764
IUP mean (MVU)	123	78–183	160	117–197	0.99	0.98–1.00	0.118
IUP maximum (MVU)	155	105–198	207	157–253	0.99	0.98–1.00	0.106
Frequency/10 min, maximum	4.0	2.5–5.2	4.7	4.0–5.0	0.64	0.37–1.10	0.105
Uterine muscle basal tone maximum (mmHg)	20	20–20	20	18–25	0.99	0.89–1.10	0.691
Tachysystole	4	50%	55	30%	2.38	0.58–9.87	0.231
Neonatal outcome							
Birthweight mean (kg)	4.0	0.4	3.7	0.5	1.14*	0.97–1.34	0.104
Composite neonatal adverse outcome**	2	25.0	27	10.3	2.89	0.55–15.55	0.207

Outcomes of labours.
SD, standard deviation.
*ORs counted per 100 g.
**Admission to neonatal intensive care unit, Apgar score <7 at 5 min or/and umbilical artery pH <7.05.
***OR counted per 100 ml.

The incidence of UR was high in our study population. This remarkably high rate may be attributed to the fact that this study population did not represent all TOLAC parturients of an ordinary birth unit, as the inclusion criterion of cervical dilatation ≤7 cm at recruitment excluded the most straightforward vaginal deliveries. In addition, the

high rates of labour induction (59%) and oxytocin augmentation (94%) reflect the study population's risk profile.[25] The incidence rate in our study did not differ from those in studies concerning TOLAC parturients who needed cervical ripening and induction of labour.[5,7] The prevalence of UR has been shown to be higher in countries with a low general CS rate and a high TOLAC rate,[2] as in Finland in general and in our study hospitals.

Induction of labour in TOLAC parturients without VD, in particular, has been reported to carry a high risk of UR (4.7%).[5] In our material, none of the UR occurred among women with previous vaginal birth. Both earlier studies[5,23] and our findings emphasize the fact that the first labour after nulliparous CS carries a special risk of UR, and induction of labour should be avoided in all such cases, where this is clinically possible.

Surprisingly, the use of a Foley catheter for induction of labour turned out to have a strong association with UR, whereas in some studies it has been considered to be a safe method,[26,27] even though there have also been controversial results.[7] It is probable that induction of labour started with an unfavourable cervix may carry a risk of UR in itself – not the method of ripening.[3] When the induction method was either amniotomy and/or oxytocin, the methods used with a more favourable cervical status, the risk of UR was even lower than in other TOLACs. Our study did not confirm the risk of prostaglandin use in relation to UR, but the use of prostaglandins among our study parturients was cautiously considered and relatively rare.

A dose–response relationship between maximum oxytocin dose and UR has been found in earlier studies,[28] but not in ours. The doses and total consumption of oxytocin during UR labours tended to be even lower than in other TOLAC cases.

Cases of uterine perforation and rupture caused by IUP catheters have been reported.[29] According to those reports, uterine perforation can often lead to hypertonicity and fetal distress – these outcomes were common (50%) among our rupture cases as well. An IUP catheter itself causing a UR can also be considered in this study. In a previous retrospective study concerning induction of labour in cases of TOLAC there was also a high incidence of UR (2.4%), and in all the rupture cases an IUP catheter had been used during labour.[5] If an IUP catheter has to be used during TOLAC, its insertion has to be carried out with particular awareness of the risk of perforation and rupture. The site of the uterine scar should be avoided, and also the site of the placenta, as the other potential complications of IUP catheter use are injuries to the fetal vessels and placenta – even placental abruption.[29]

Strengths and limitations

The strength of our study is that case by case we analysed a large amount of data on contractions in TOLAC parturients. Earlier studies of TOLAC parturients' uterine contractility activity are sparse. The analyses were carried out by doctors, not computers, which simulates the real situation in labour wards. Two investigators interpreted the tocograms, which diminishes the variation of interpretation of contractions. A weakness could be considered to be the fact that the original study, i.e. the parent study, was not designed to investigate UR or to study the differences in uterine activity, so the original power calculations were not carried out with this in mind.

Conclusion

Uterine contractile activity is greater and rises linearly toward the birth of a neonate when TOLAC succeeds. During VBAC, the response to oxytocin in terms of contractile activity is adequate, in contrast to failed TOLAC. Uterine contractile activity does not differ generally between rupture cases and others in TOLAC. Induction of labour with a Foley catheter without previous VD and with an unfavourable cervix carries a risk of UR. In future, a safe cervical ripening protocol and time-point for induction of labour in TOLAC parturients should be studied further, especially among women with no previous vaginal delivery, because both the prolongation of gestation and the induction of labour with an unripe cervix carry risks of failed TOLAC and rupture.

Disclosure of interests

None declared. Completed disclosure of interests form available to view online as supporting information.

Contribution to authorship

All authors contributed to the design of this study. TH was responsible for data gathering, and data analysis was performed by TH together with HH. All authors contributed to reporting the work and results. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Details of ethics approval

Ethics approval for the original randomised controlled trial was given by the Ethics Committee of Pirkanmaa Hospital District (R12229) in October 2012. Approval included retrospective analysis of contractions.

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Data availability statement

The full data set is available from the corresponding author on reasonable request.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Cardiotocograms of uterine ruptures.
Figure S2. Cardiotocograms of uterine ruptures.
Figure S3. Cardiotocograms of uterine ruptures.
Figure S4. Cardiotocograms of uterine ruptures.
Figure S5. Cardiotocograms of uterine ruptures.
Figure S6. Cardiotocograms of uterine ruptures.
Figure S7. Cardiotocograms of uterine ruptures.
Figure S8. Cardiotocograms of uterine ruptures.
Table S1. Labour characteristics of uterine ruptures and clinically significant fenestrations. ■

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