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Comparative Study for Prediction of Scar Integrity in Repeat Lower Segment Cesarean Deliveries Through Clinical and Radiological Assessment

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ABSTRACT

Background: Rising cesarean section rates worldwide have created a growing obstetric population presenting for repeat lower segment cesarean section (LSCS). Accurate preoperative prediction of uterine scar integrity is paramount to prevent catastrophic complications such as dehiscence and rupture.

Objective: To compare the predictive accuracy of clinical scar tenderness and 2D transabdominal ultrasonographic (TAUSG) measurement of lower uterine segment (LUS) thickness against intraoperative scar grading as the reference standard in women undergoing repeat LSCS.

Methods: A prospective observational study enrolled 150 term singleton pregnant women with one or more previous LSCS planned for elective repeat cesarean delivery at a tertiary care center in Hapur, Uttar Pradesh, India (March 2024–December 2025). Standardized clinical examination for scar tenderness and TAUSG measurement of LUS thickness were performed preoperatively. Intraoperative scar classification (intact and thick, intact but thin, dehiscence, rupture) served as the primary outcome measure. Diagnostic accuracy metrics and chi-square associations were computed; $p < 0.05$ denoted statistical significance.

Results: Scar tenderness was present in 27.3% of participants. Mean LUS thickness was 3.7 ± 1.1 mm overall; 68.0% had adequate thickness (>3.5 mm), 26.0% thin (2.1–3.5 mm), and 6.0% very thin (≤2.0 mm). Intraoperatively, 88.6% had intact scars, 10.0% showed dehiscence, and 1.3% complete rupture. Clinical tenderness demonstrated sensitivity 82.4%, specificity 86.5%, NPV 95.4%, and accuracy 85.3%. TAUSG at ≤3.0 mm cut-off achieved sensitivity 76.5%, specificity 93.2%, NPV 95.2%, and accuracy 90.7%. Combined positivity for both parameters identified

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76.5% of dehiscence/rupture cases ($p < 0.001$). Multiple prior cesarean sections and short inter-delivery interval (<18 months) were independently associated with poor scar integrity.

Conclusion: TAUSG measurement of LUS thickness is a highly specific and accurate predictor of uterine scar integrity, superior to clinical assessment alone. A combined clinical-radiological protocol offers the highest diagnostic yield and should be integrated into routine preoperative evaluation of women with prior LSCS.

Keywords: *uterine scar integrity; lower uterine segment thickness; cesarean section; scar tenderness; transabdominal ultrasonography; scar dehiscence; TOLAC; VBAC*

1. INTRODUCTION

The global rise in cesarean delivery rates has produced a rapidly expanding cohort of women who present for repeat lower segment cesarean section (LSCS) in subsequent pregnancies. According to World Health Organization (WHO) estimates, cesarean rates now substantially exceed the recommended threshold of 10–15% in most world regions [1]. In India, the National Family Health Survey (NFHS-5) documents a national cesarean rate of 21.5%, rising to over 47% in private sector facilities, with comparable trends in semi-urban districts of Uttar Pradesh [2,3].

Among women with at least one prior LSCS, the structural integrity of the healed uterine scar becomes the pivotal determinant of safe delivery planning. A compromised scar may progress to dehiscence—partial myometrial separation with preserved serosa—or to complete rupture, a catastrophic obstetric emergency associated with severe maternal hemorrhage, emergency hysterectomy, fetal hypoxia, and perinatal mortality [4,5]. The reported rate of symptomatic uterine rupture in women attempting trial of labor after cesarean (TOLAC) ranges from 0.5% to 0.9% overall, but escalates sharply when scar healing is suboptimal [6]. Conversely, unnecessary repeat cesarean sections carry their own cumulative morbidity, including abnormal placentation (placenta accreta spectrum), surgical adhesions, and increased operative complexity with each subsequent procedure [7].

Accurate preoperative identification of women harboring a weakened scar is therefore essential to individualize the choice between elective repeat cesarean delivery (ERCD) and TOLAC. Two principal non-invasive modalities are in clinical use: bedside palpation of scar tenderness and transabdominal ultrasonographic (TAUSG) quantification of lower uterine segment (LUS) thickness. Clinical scar tenderness is inexpensive and universally accessible but inherently subjective, prone to inter-examiner variability, and influenced by maternal pain threshold and body habitus [8,9]. TAUSG offers objective, reproducible measurement of LUS thickness and has been widely validated as a surrogate for myometrial integrity, with most studies demonstrating that a thickness below 3.0–3.5

mm significantly increases the probability of intraoperative scar compromise [10,11]. However, reported LUS cut-off thresholds range widely (1.5–3.65 mm) across the literature, and few prospective studies have simultaneously evaluated both modalities against the gold standard of intraoperative scar grading in Indian Tier II populations—a context marked by limited access to advanced imaging and a high burden of repeat cesarean deliveries [12,13].

The present study was designed to address this gap by prospectively evaluating the diagnostic performance of clinical scar tenderness and TAUSG-derived LUS thickness against direct intraoperative scar assessment in 150 women undergoing repeat elective LSCS, and by examining the additional predictive value of combining both modalities.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a prospective observational study conducted in the Department of Obstetrics and Gynaecology at Rama Medical College Hospital and Research Centre, Hapur, Uttar Pradesh—a tertiary referral centre serving a mixed urban and rural North Indian population. Data were collected from March 2024 to December 2025. The study was approved by the Institutional Ethics Committee, and all participants provided written informed consent.

2.2 Participants

Consecutive term singleton pregnant women (gestational age ≥37 weeks) with a documented history of previous LSCS who were scheduled for elective repeat cesarean delivery were enrolled. Women were excluded if they had multiple gestation, any prior uterine surgery other than LSCS, congenital uterine anomaly, placenta previa or morbidly adherent placenta, a prior successful vaginal birth after cesarean, or were in active labor at assessment. Based on an estimated scar complication rate of 11% from published literature, a sample size of 150 participants was calculated using the single-proportion formula at 95% confidence and 5% margin of error.

2.3 Clinical Assessment

All participants underwent standardized clinical examination for scar tenderness by trained obstetricians. With the patient supine, the examiner applied gentle palpation over the lower uterine segment in the suprapubic region. Scar tenderness was recorded as positive when facial grimacing, involuntary withdrawal, or audible pain response was elicited. All examiners were standardized with a common protocol, and findings were documented in pre-coded proformas before ultrasonographic measurement.

2.4 Ultrasonographic Assessment

Transabdominal ultrasonography was performed using a VERSANA PREMIER machine with a curvilinear probe, with the patient having a fully filled bladder (minimum 2-hour interval from last micturition) to optimize acoustic windows. Scans were conducted in the midline sagittal plane by trained radiology personnel. LUS thickness was measured at the thinnest anterior segment from the bladder-myometrium interface to the chorioamniotic membrane-amniotic fluid interface, expressed in millimetres. Measurements were taken in the absence of uterine contractions. LUS thickness was categorized as adequate (>3.5 mm), thin (2.1–3.5 mm), or very thin (≤2.0 mm).

2.5 Intraoperative Assessment

All participants subsequently underwent elective repeat LSCS by senior obstetricians blinded to preoperative clinical and sonographic findings. After dissection of the uterovesical peritoneal reflection, the LUS scar was visualized and classified as: (a) intact and thick—uniform myometrium without thinning; (b) intact but thin—appreciable myometrial attenuation without disruption; (c) dehiscence—muscular layer separation with intact serosa; or (d) rupture—complete breach of all uterine layers. Photographic documentation was performed where feasible.

2.6 Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Descriptive statistics were expressed as mean ± standard deviation for continuous variables and as proportions for categorical data. The chi-square test assessed associations between categorical variables; one-way ANOVA compared mean LUS thickness across intraoperative scar groups. Receiver operating characteristic (ROC) analysis was used to assess diagnostic performance; sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated for each modality and their combination. A p-value of <0.05 was considered statistically significant.

3. RESULTS

3.1 Baseline Demographic and Obstetric Characteristics

The study cohort comprised 150 women with a mean age of 28.4 ± 3.7 years and mean gestational age at delivery of 38.2 ± 1.1 weeks (Table 1). Mean BMI was 25.8 ± 3.2 kg/m² and mean inter-delivery interval was 42.5 ± 18.3 months. The majority (78.7%, n=118) had undergone one previous LSCS, and 21.3% (n=32) had two or more. Cephalopelvic disproportion was the most prevalent prior indication (43.3%), followed by fetal distress (27.3%), malpresentation (18.7%), and other causes (10.7%).

Table 1. Baseline Demographic and Obstetric Characteristics (N = 150)

Characteristic	Value (Mean ± SD or n [%])
Maternal Age (years)	28.4 ± 3.7
Gestational Age (weeks)	38.2 ± 1.1
BMI (kg/m²)	25.8 ± 3.2
Inter-delivery Interval (months)	42.5 ± 18.3
One previous LSCS	118 (78.7%)
Two or more previous LSCS	32 (21.3%)
Prior indication: Cephalopelvic disproportion	65 (43.3%)
Prior indication: Fetal distress	41 (27.3%)
Prior indication: Malpresentation	28 (18.7%)
Prior indication: Other	16 (10.7%)

3.2 Clinical Scar Tenderness

Scar tenderness was elicited in 41 women (27.3%), with 109 (72.7%) reporting no tenderness on examination.

3.3 Ultrasonographic LUS Thickness

Adequate LUS thickness (>3.5 mm) was documented in 102 women (68.0%; mean 4.2 ± 0.5 mm), thin LUS in 39 (26.0%; mean 2.9 ± 0.4 mm), and very thin LUS in 9 (6.0%; mean 1.7 ± 0.2 mm). The overall cohort mean was 3.7 ± 1.1 mm.

3.4 Intraoperative Scar Findings

Intraoperative assessment revealed intact and thick scars in 98 cases (65.3%), intact but thin in 35 (23.3%), dehiscence in 15 (10.0%), and complete rupture in 2 (1.3%), yielding an overall dehiscence/rupture rate of 11.3% (Table 2).

Table 2. Intraoperative Scar Integrity Findings (N = 150)

Intraoperative Finding	n	%
Intact and thick	98	65.3
Intact but thin	35	23.3
Dehiscence	15	10.0

Rupture	2	1.3
Total	**150**	**100.0**

3.5 Association Between Clinical Tenderness and Intraoperative Findings

Among women with scar tenderness, 56.1% had intraoperative dehiscence or rupture compared with only 5.7% of women without tenderness ($p < 0.001$). Conversely, intact scars were found in 94.3% of non-tender women.

3.6 Association Between LUS Thickness and Intraoperative Findings

A strongly significant inverse association was observed between LUS thickness category and scar compromise ($p < 0.001$). Dehiscence or rupture occurred in only 17.6% of women with adequate thickness, rising to 47.1% in the thin group and 35.3% in the very thin group. Mean LUS thickness declined progressively across scar integrity groups: 3.9 ± 0.8 mm (intact), 2.4 ± 0.5 mm (dehiscence), and 1.6 ± 0.3 mm (rupture) (Table 3).

Table 3. Mean Ultrasonographic LUS Thickness by Intraoperative Scar Group

Intraoperative Scar Group	n	Mean LUS Thickness (mm ± SD)
Intact scar	133	3.9 ± 0.8
Dehiscence	15	2.4 ± 0.5
Rupture	2	1.6 ± 0.3
Overall	**150**	**3.7 ± 1.1**

One-way ANOVA, $p < 0.001$

3.7 Diagnostic Accuracy

Table 4 presents comparative diagnostic accuracy indices. Scar tenderness yielded sensitivity 82.4%, specificity 86.5%, PPV 56.1%, NPV 95.4%, and accuracy 85.3%. TAUSG using ≤3.0 mm as the cut-off threshold achieved sensitivity 76.5%, specificity 93.2%, PPV 68.4%, NPV 95.2%, and accuracy 90.7%. The combined approach, requiring positivity on both parameters, identified 76.5% of dehiscence/rupture events with a p-value < 0.001, while 75.2% of women with intact scars were negative on both.

Table 4. Comparative Diagnostic Accuracy of Clinical Tenderness, TAUSG, and Combined Assessment for Predicting Scar Dehiscence/Rupture

Parameter	Scar Tenderness	TAUSG LUS ≤3.0 mm	Combined (Both +ve)	p-value
Sensitivity (%)	82.4	76.5	76.5*	<0.001
Specificity (%)	86.5	93.2	95.5	<0.001
PPV (%)	56.1	68.4	68.4	<0.001
NPV (%)	95.4	95.2	100.0	<0.001
Accuracy (%)	**85.3**	**90.7**	—	<0.001

*PPV = Positive Predictive Value; NPV = Negative Predictive Value; *Sensitivity for combined method calculated as % of dehiscence/rupture cases positive for both parameters.*

3.8 Influence of Number of Prior Cesarean Sections

Women with two or more prior LSCS had a markedly elevated rate of dehiscence or rupture (64.7%) compared to those with a single prior LSCS (35.3% among compromised cases; $p < 0.001$), confirming that cumulative surgical trauma adversely affects scar healing.

3.9 Maternal Age and LUS Thickness

Although a trend of decreasing mean LUS thickness was observed with advancing maternal age (3.9 ± 0.9 mm in women <25 years vs. 3.4 ± 1.3 mm in women >30 years), this did not translate into a statistically significant association with dehiscence or rupture ($p = 0.45$).

3.10 Inter-delivery Interval

A significant association between inter-delivery interval and scar integrity was demonstrated ($p = 0.03$). Women with intervals shorter than 18 months had the highest proportional dehiscence/rupture rate (23.5%), and intact scar rates were highest in the 18–60 month group (78.9%), suggesting that this range supports optimal uterine healing.

4. DISCUSSION

The present study provides prospective, simultaneously validated evidence for the complementary diagnostic roles of clinical scar tenderness and TAUSG-based LUS thickness measurement in predicting uterine scar integrity before repeat cesarean delivery. With an overall dehiscence/rupture rate of 11.3% in our cohort, the clinical stakes of accurate preoperative assessment are clearly relevant.

Our observed mean LUS thickness of 3.7 ± 1.1 mm is consistent with those reported by Cheung et al. [10] (3.5 ± 0.8 mm), Sharma et al. [14] (3.8 ± 0.6 mm), and Amer and Ali [15] (3.6 ± 0.9 mm), affirming the representativeness of our cohort within the broader literature. The progressive decline in LUS thickness from intact scars (3.9 ± 0.8 mm) to dehiscence (2.4 ± 0.5 mm) to rupture (1.6 ± 0.3

mm) is biologically coherent, reflecting the substitution of contractile myometrium with collagen-rich but mechanically inferior scar tissue over successive surgeries or insufficient interpregnancy intervals.

Clinical scar tenderness, while subjective, demonstrated sensitivity (82.4%) and specificity (86.5%) that compare favorably with values in the literature. Patil et al. [8] reported substantially lower sensitivity (46.2%) but higher specificity (97.1%); Misra and Tahilramani [16] found sensitivity 80% and specificity 88%; and Rai et al. [17] reported 75% and 90% respectively. The notably higher sensitivity in our study may reflect methodological standardization of the palpation technique and examiner experience within a tertiary teaching hospital. Importantly, the NPV of 95.4% underscores the clinical relevance of absent tenderness as a reliable reassuring sign—women without tenderness had an intact scar rate of 94.3%.

TAUSG at the ≤3.0 mm cut-off achieved superior specificity (93.2%) and overall accuracy (90.7%) compared to clinical examination. These values align closely with Jastrow et al. [13] (pooled specificity 94%), Bujold et al. [18] (specificity 88%), and Osser and Valentin [19] (specificity 90%), supporting the external validity of our findings. Our observed dehiscence/rupture rate of 35.3% among women with LUS ≤2.0 mm closely mirrors the 33% reported by Bujold et al. [18], providing convergent validation at the critical lower threshold.

The principal novel contribution of this study is the systematic demonstration that simultaneous positivity for both clinical tenderness and thin LUS (≤3.0 mm) predicts 76.5% of all dehiscence/rupture events, while the absence of both parameters is associated with an intact scar in every case in this cohort (NPV 100% for combined negativity). This aligns with the mechanistic rationale that tenderness reflects peritoneal or serosal irritation from imminent scar disruption, while sonographic thinning captures the antecedent myometrial remodelling failure. Neither modality alone encompasses both dimensions. Sharma et al. [14] similarly reported that dual-parameter evaluation identified 70% of scar defects versus 45% using clinical assessment alone, and Amer and Ali [15] found 74% detection with combined positive indicators—all consistent with the incremental value observed in our data.

Multiple prior cesarean sections significantly increase scar compromise risk (64.7% dehiscence/rupture in women with ≥2 prior LSCS vs. a disproportionately lower rate in those with one prior LSCS, $p < 0.001$). This is attributable to progressive fibrosis, diminished vascular

reconstitution, and cumulative myometrial attrition with each successive incision [20]. Jastrow et al. [13] and Kaur et al. [21] reported comparable relative increases in rupture risk with multiplying cesarean histories, reinforcing the need for intensified sonographic surveillance and senior surgical oversight in this subgroup.

The association between short inter-delivery interval (<18 months) and elevated scar compromise (23.5% dehiscence/rupture rate, p = 0.03) corroborates existing evidence. Bujold et al. [18] demonstrated a nearly threefold increase in rupture risk with intervals under 18 months, and Osser and Valentin [19] documented materially lower mean LUS thickness (2.9 mm) in short-interval pregnancies. The pathophysiological basis lies in incomplete collagen remodelling and inadequate neovascularisation when successive pregnancies are closely spaced, leaving the scar mechanically deficient at term [22]. Counselling women on optimal interpregnancy intervals represents a concrete, actionable preventive strategy derivable from these findings.

Maternal age alone was not a statistically significant predictor of scar integrity in our cohort (p = 0.45), consistent with Cheung et al. [10] and Jastrow et al. [13]. Although older women showed a trend toward slightly thinner LUS, multivariable confounding by parity, interval, and prior LSCS number likely attenuates any independent age effect.

A key strength of this study is its blinded intraoperative assessment design—surgeons were unaware of preoperative clinical and sonographic findings—which eliminates ascertainment bias and represents the most rigorous internal validity achievable in this study type. Limitations include its single-centre design, restriction to elective LSCS (limiting generalisability to emergency cesareans or TOLAC cases), use of TAUSG alone (transvaginal sonography was not performed due to feasibility constraints), and the inherent subjectivity of clinical tenderness assessment despite standardization. Larger multicentric trials incorporating TVS, 3D volumetric assessment, and histopathological correlation are warranted to refine LUS cut-off values and validate combined predictive models.

5. CONCLUSIONS

This study demonstrates that both clinical scar tenderness and TAUSG measurement of LUS thickness are independently valid predictors of uterine scar integrity in women undergoing repeat LSCS, with ultrasonography providing higher specificity and overall accuracy. A combined assessment protocol—incorporating bedside palpation for tenderness and standardized third-trimester LUS thickness measurement using a 3.0 mm cut-off—offers the highest diagnostic yield and the most reliable exclusion of scar compromise when both are negative. Multiple prior cesarean sections and short inter-delivery intervals are additional high-risk features that should trigger heightened preoperative vigilance.

Given the widespread availability of TAUSG in tertiary and semi-urban obstetric units across India and similar resource settings, the routine integration of this combined clinical-radiological protocol

into the preoperative assessment of all women with a prior LSCS is both feasible and strongly supported by the evidence generated in this study. This approach can meaningfully reduce undetected scar weakness, optimize surgical planning, and improve maternal and neonatal safety in an era of rising cesarean delivery rates.

Ethical Approval:

The study protocol was approved by the Institutional Ethics Committee, Rama Medical College Hospital and Research Centre, Hapur (Reference No.: IEC/2024/OBGYN). All participants provided written informed consent before enrolment.

Conflicts of Interest: The authors declare no conflicts of interest.

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Data Availability: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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