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RESEARCH ARTICLE

Accuracy of sonographic lower segment thickness and prediction of vaginal birth after caesarean in a resourced-limited setting; Prospective study

Charles Adu-Takyi[1] | **Rafique Munazzah**[2] | **Yaw Gyanteh Owusu**[1] | **Atta Owusu-Bempah**[1] | **Bernard Arhin**[3] | **Henry Sakyi Opare-Addo**[1,4] | **Amponsah Peprah**[1,4] | **Sally L. Collins**[5] | **Theophilus Adu-Bredu**[1,5]

[1]Department of Obstetrics and Gynaecology Directorate, Komfo Anokye Teaching Hospital, Kumasi, Ghana

[2]Women's Centre, John Radcliffe Hospital, Oxford, UK

[3]Research and Development Unit, Komfo Anokye Teaching Hospital, Kumasi, Ghana

[4]Obstetrics and Gynaecology Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[5]Nuffield Department of Women's and Reproductive Health, University of Oxford, Oxford, UK

Correspondence
Theophilus Adu-Bredu, Nuffield Department of Women's and Reproductive Health, University of Oxford, Oxford, England.
Email: theophilus.adu-bredu@wrh.ox.ac.uk

Abstract

Objectives: To assess the accuracy of ultrasound measurement of the lower uterine segment (LUS) thickness against findings at laparotomy, and to investigate its correlation with the success rate of vaginal birth after one previous caesarean delivery (CD) in a resource-limited setting.

Design: Prospective study.

Setting: Obstetrics and Gynaecology department in a tertiary hospital in Ghana.

Population: Women with one previous CD undergoing either a trial of labour (TOLAC) or elective CD.

Methods: Myometrial lower uterine segment thickness (mLUS) and full lower uterine segment thickness (fLUS) were measured with transvaginal ultrasound (TVUS). The women were managed according to local protocols with the clinicians blinded to the ultrasound measurements. The LUS was measured intraoperatively for comparison with ultrasound measurements.

Main outcome measures: Lower uterine segment findings at laparotomy, successful vaginal birth.

Results: A total of 311 pregnant women with one previous CD were enrolled; 147 women underwent elective CD and 164 women underwent a TOLAC. Of the women that underwent TOLAC, 96 (58.5%) women had a successful vaginal birth. The mLUS was comparable to the intraoperative measurement in the elective CD group with LUS thickness <5 mm (bias of 0.01, 95% CI −0.10 to 0.12 mm) whereas fLUS overestimated LUS <5 mm (bias of 0.93, 95% CI 0.80–1.06 mm). Successful vaginal birth rate correlated with increasing mLUS values (odds ratio 1.30, 95% CI 1.03–1.64). Twelve cases of uterine defect were recorded. LUS measurement ≤2.0 mm was associated with an increased risk of uterine defects with a sensitivity of 91.7% (95% CI 61.5–99.8%) and specificity of 81.8% (95% CI 75.8–86.8%).

Conclusion: Accurate TVUS measurement of the LUS is technically feasible in a resource-limited setting. This approach could help in making safer decisions on mode of birth in limited-resource settings.

KEYWORDS
caesarean delivery, limited-resource setting, lower uterine segment, trial of labour, ultrasound measurement, uterine rupture, vaginal birth after caesarean

1 | INTRODUCTION

There has been a global increase in the rate of caesarean deliveries (CD) in recent years. CD now accounts for more than 1 in 5 births, and this is predicted to rise to almost a third by 2030.[1] When clinically indicated, CD is of great value for preserving the lives of both mother and baby; however, like all major surgery, it carries associated risks and complications. After an iatrogenic injury, the uterus has been demonstrated to show an altered healing pattern, leaving elastosis, tissue oedema and myofibre disarray[2] with reduced smooth muscle density.[3] The presence of this scarred tissue increases the risk of complications such as uterine rupture, scar dehiscence and placenta accreta spectrum in subsequent pregnancies.[4–8] At term, uterine blood flow reaches approximately 800 mL/min,[9] hence in the event of a uterine rupture, rapid and substantial blood loss ensues, resulting in adverse outcomes for both the mother and baby.[10] In a low- or middle-income country, uterine rupture may result in greatly increased maternal and perinatal mortality[11] as a result of limited resources, including inadequate access to an emergency theatre, availability of skilled personnel, and lack of blood and blood products. As a result, previous CD has become one of the leading indications for a repeat CD in Ghana.[12,13]

Vaginal birth after caesarean delivery (VBAC) has gained traction in recent years because of its success rate,[14,15] but identifying which women are likely to have a successful VBAC remains challenging. In high-income countries with highly skilled birth attendants, appropriate intrapartum monitoring (cardiotocography) and recourse to rapid emergency CD, VBAC has been demonstrated to be safe. However, correct selection of candidates and careful monitoring in labour are essential to avoid adverse outcomes for the mother and baby.[15] In clinical settings with constrained intrapartum resources, accurate assessment of the likelihood of uterine rupture is crucial. If the risk of rupture is low, then VBAC may be recommended. This should help to lower the incidence of subsequent CD, thereby reducing the risk of developing other sequelae from multiple CDs such as placenta accreta spectrum. Various professional societies and organisations have suggested several criteria to guide patient selection for attempting VBAC; however, the implementation of these criteria varies widely and is frequently devoid of high-quality evidence.[16–18] Moreover, these criteria might not be readily applicable in limited-resource settings.

Several studies have proposed thinning of the lower uterine segment (LUS), measured by ultrasound, as a useful tool in predicting uterine rupture in labour.[19,20] However, these studies have been hindered by relatively small sample sizes and variations in ultrasound methodology. Consequently, divergent cutoff values have emerged, further complicating the interpretation of results to support its inclusion in clinical practice. In this study, we assessed the accuracy of ultrasound LUS measurement compared with direct assessment and measurement at laparotomy. Also, we explored its correlation to the success rate of patients aiming for a VBAC as well as the fetal and maternal outcomes in a limited-resource-setting.

2 | METHODS

This prospective study was conducted among women with one previous CD who were scheduled for delivery at Komfo Anokye Teaching Hospital, Ghana between 8 November 2021 and 30 November 2022. Ethical approval was obtained from the Komfo Anokye Teaching Hospital Institutional Review Board before the start of the study (KATH IRB/AP/117/21). This study included women with singleton pregnancies with one previous caesarean birth beyond 32 completed weeks of gestation that were scheduled for an elective CD or a trial of labour (TOLAC). Participants with more than one previous CD were excluded from the study. Participants were recruited before the onset of established labour or planned elective CD and their written, informed consent was gained.

2.1 | Sonographic technique and measurement

A literature review was first conducted to determine the appropriate sonographic technique to be used in the LUS measurement. PubMed, Scopus and Google Scholar were searched for articles published on the reliability and accuracy of the sonographic techniques. The search terms used were inclusive of the Medical Subject headings under the following terms, 'uterine rupture', 'caesarean section', 'vaginal birth after caesarean'. These were combined with terms related to the ultrasound technique like 'lower uterine segment thickness', 'transabdominal', 'transvaginal' and '3D ultrasound'. The literature search yielded 13 articles that explored accuracy and inter- and intra-operator reliability of sonographic techniques.[21-33] Out of these studies, 7 (53.8%) compared both transabdominal and transvaginal techniques to the actual intraoperative measurement of LUS and found the transvaginal technique to be more accurate.[22-24,26,29-31] Transvaginal ultrasound (TVUS) also proved to have a higher inter- and intra-operator reliability compared with transabdominal ultrasound.[32,33] Four studies compared the inter-operator reliability of two-dimensional (2D) and three-dimensional (3D) assessment of the LUS.[21,25,27,33] Among them, three studies[25,27,33] found 3D ultrasound to have a better inter-operator reliability. In contrast, one study[21] did not find any significant difference in the inter-operator reliability between the two techniques. Another study[29] compared the accuracy of both techniques to the intraoperative measurements and found no difference between 2D and 3D (Table S1). The measurement techniques used by the studies were heterogeneous: while some measured full LUS thickness[32] or myometrial LUS thickness alone,[22,23,26,30,31] others measured both.[21,24,27,29,33]

Based on the findings of this review, measurement of the LUS for this study was performed using the 2D transvaginal

approach. To ensure consistency in the technique, measurements were performed by a single operator (TAB). The sonographic examinations were performed with a Siemens Acuson NX 3 machine equipped with a 5- to 8-MHz endocavity probe. Initially, a transabdominal scan was conducted to ensure that the urinary bladder was adequately filled, which facilitated a clear visualisation of the LUS. The operator then proceeded with TVUS. The LUS was identified in the longitudinal plane and zoomed-in to occupy approximately 75% of the image. The LUS appears sonographically as a three-layered structure consisting of a superficial echogenic layer, which represents the serosa, the inner denser hypoechoic layer of the myometrium and the inner echogenic layer of the endometrium. The LUS measurements were taken according to the methodology of Bujold et al.[34] LUS measurements were taken at the area with the minimum thickness at the LUS. The full LUS thickness(fLUS) was measured with one calliper at the inner wall of the urinary bladder and the other calliper at the interface between the amniotic fluid and the decidua. The myometrial LUS (mLUS) recorded was the minimum thickness of the middle dense hypoechoic layer (Figure 1). Three measurements were taken in the midline, sagittal plane and the minimum measurement found was recorded as the LUS thickness.

The ultrasound measurements were performed on the same day after the woman's appointment with the attending obstetrician on the planned mode of delivery. The LUS measurement was not recorded in the patient's notes, so both the attending obstetricians and patients were blinded to the ultrasound findings. Patient who opted for a repeat elective CD, were delivered within a week, whereas those planning for a TOLAC waited until onset of labour.

2.2 | Intra-operative (direct) assessment and measurement of LUS myometrial thickness

Intraoperatively, the thickness of the LUS was measured by the surgeon after delivery of the baby using a sterile plastic ruler and the following technique: two Green-Armytage forceps were applied to gently grasp the lower flap of the uterus about 5 cm apart on either side of the midline. The flat upper end of a grasping forceps was placed on the inner aspect of the LUS between the two Green-Armytage forceps to demarcate the inner surface of the LUS. A sterile ruler was placed on the lower flap of the incision at a right angle to the surface of the grasping forceps and the measurement was taken (Figure 2). The surgeon was blinded to the ultrasound measurement.

Uterine defect was described as the disruption and separation of the uterine scar. It was classified as either scar dehiscence or uterine rupture. Scar dehiscence was described as the presence of a uterine defect with intact serosa. Uterine rupture was defined as the presence of a uterine defect with contents (fetus, amniotic fluid/membranes) expelled into the abdominal cavity. The identification of only thinned lower uterine segment at laparotomy was not classified as scar dehiscence.

2.3 | Other variables collected

Maternal history data collected included: maternal age, gestational age at delivery, interpregnancy interval, number of previous VBACs and indication for the previous CD. Variables assessed for the mode of delivery were: intended mode of delivery, spontaneous vaginal delivery, indication for CD and any complications of the mode of delivery including postpartum haemorrhage, uterine rupture, severe morbidity requiring intensive care unit admission, organ injury and maternal death. Neonatal variables collected included: Apgar score in the 1st and 5th minute after birth, birthweight, presence or absence of meconium-stained amniotic fluid and the grade of any meconium-stained amniotic fluid (grades 1, 2, 3),[35] admission to neonatal intensive care unit and reason for admission, and perinatal death.

2.4 | Data management and statistical analysis

Analysis of data was performed using SPSS version 21.0 (IBM, Armonk, NY, USA). The Shapiro–Wilk normality test[36] was first performed to determine the distribution

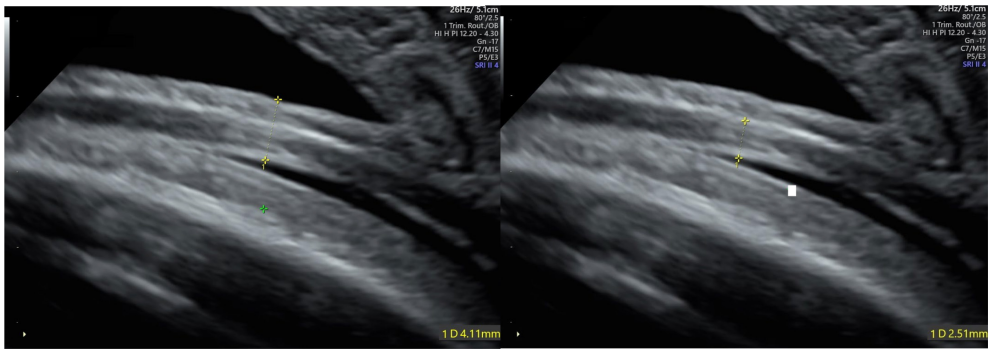

FIGURE 1 Transvaginal measurement of the lower uterine segment. Full lower uterine segment measurement is seen on the left and the myometrial lower uterine segment measurement is seen on the right.

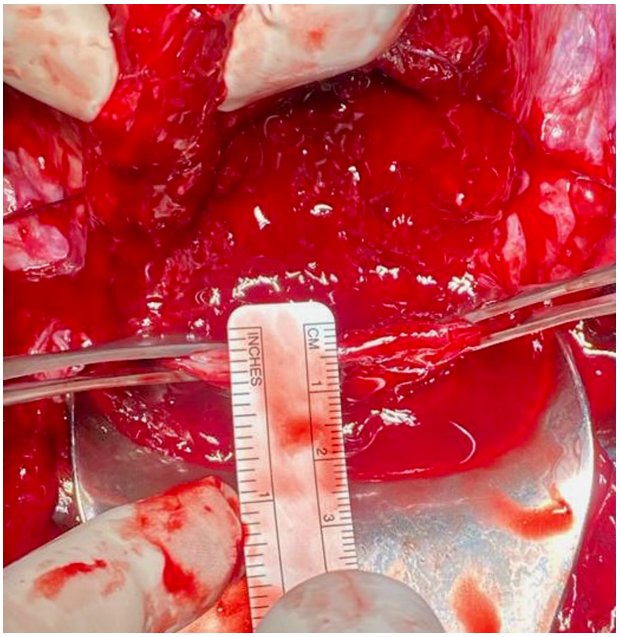

FIGURE 2 Intraoperative measurement of the lower uterine segment.

of the variables and the type of statistical analysis to use. Categorical variables were reported as frequencies with their percentages in tables. Continuous or numerical variables were presented as mean, with the standard deviation if normally distributed, or median, with interquartile ranges if not normally distributed. Chi-square test or Fisher's exact test was used to determine levels of significant associations. The independent *t* test or Mann–Whitney *U* test was used to compare two means or mean ranks, and the chi-square test was used to compare proportions. A scatter plot was used to visually assess the relationship between actual LUS measured intraoperatively and the discrepancy observed in ultrasound measurements (difference between actual LUS and ultrasound measurements; Figures S1 and S2). A Bland–Altman plot was used to determine the accuracy of the ultrasound LUS measurement. Diagnostic test of accuracy was determined using the receiver operating characteristics curves. Using a confidence interval of 95%, a *p* value of 0.05 or less was accepted as statistically significant. No corrections for multiple comparisons were applied.

2.5 | Mid-study protocol change

In light of local challenges pertaining to documentation and health record maintenance, the data collection team closely monitored patient outcomes to prevent any potential loss of data. After two perinatal deaths from uterine rupture occurred in women with mLUS recorded as 1.9 and 2 mm on ultrasound scan, the data underwent an interim analysis. At that point, 129 participants had been recruited and 11 women with an mLUS of ≤2 mm had attempted a VBAC. None had achieved a successful vaginal delivery with all having an emergency CD in labour, five of which were found to have a scar dehiscence and two experienced a uterine rupture resulting in two intrapartum perinatal deaths. At this point, on the basis of patient safety, the protocol was revised to exclude a planned TOLAC for women with a LUS measurement of ≤2 mm. If after recruitment, the mLUS was found to be ≤2 mm, the woman's attending physician was contacted and elective CD was recommended (Tables S2 and S3). This mid-study protocol change led to the exclusion of three patients who had previously planned to have TOLAC but who were found to have an mLUS of ≤2 mm on TVUS scan.

3 | RESULTS

In this study, 314 pregnant women who had previously undergone one previous CD provided their consent. However, three were excluded because of the mid-study protocol change. As a result, our study ultimately included 311 participants. A total of 147 women opted for a repeat CD and 164 underwent TOLAC. Of the 164 participants that underwent TOLAC, 96/164 (58.5%) were successful and 68/164 (41.5%) were delivered by emergency CD. Patient characteristics are detailed in Table 1. The indications for the emergency CD grouped according the mLUS measurement are given in Table 2.

The mean duration between the ultrasound examination and delivery was 2 ± 4 days. To evaluate the accuracy of the TVUS measurements of the LUS, it was compared with the intraoperative measurements in the elective CD group. For the mLUS measurements, Bland–Altman plot analysis revealed proportional bias, indicating that it is more comparable with smaller LUS values and tended to underestimate larger LUS values (Figure 3). A subgroup analysis further elucidated this pattern ($p < 0.001$), demonstrating good comparability with ultrasound in LUS values <5 mm (bias of 0.01, 95% CI −0.10 to 0.12 mm) compared with LUS values ≥5 mm (bias of 0.66, 95% CI 0.37–0.96 mm; Figure S1). Similarly, for the fLUS measurements, proportional bias was noted on the Bland–Altman plot. However, smaller LUS values were overestimated while larger LUS values were comparable (Figure 3). A subgroup analysis confirmed this pattern ($p = 0.029$), as measurements of fLUS tended to overestimate values <5 mm (bias of 0.93, 95% CI 0.80–1.06 mm) but were comparable with values ≥5 mm (bias of 0.35, 95% CI 0.04–0.65 mm; Figure S2). Considering the clinical implication of the accuracy of smaller LUS thickness, mLUS ultrasound measurement was deemed more appropriate and clinically relevant. Hence, further analysis was based on this approach.

For the TOLAC group, statistically significant difference in the mLUS thickness was observed between the successful and failed VBAC groups (3.97 ± 1.4 versus 3.46 ± 1.42, $p = 0.026$). The mLUS thickness in the group with a previous VBAC was higher compared with the group without a previous VBAC (4.77 ± 1.75 versus 3.31 ± 1.68, $p < 0.001$). However,

TABLE 1 Patient demographics and birth outcomes classified according to the myometrial lower uterine segment thickness.

Characteristics	Myometrial lower uterine segment thickness		
	≤2 mm (*n* = 48)	2.1–2.9 mm (*n* = 70)	≥3 mm (*n* = 193)
Patient demographics			
Age (years)[a]	30.88 ± 4.57	28.4 ± 5.05	32.3 ± 5.05
Parity[b]			
1	29 (60.4%)	44 (62.9%)	61 (31.6%)
2	12 (25%)	13 (18.6%)	58 (30.0%)
≥3	7 (14.6%)	13 (18.6%)	74 (38.3%)
Inter-pregnancy interval[b]	25.6 ± 26.7	24.95 ± 18.1	44.44 ± 31.35
Number of previous VBAC[b]			
None	45 (93.8%)	64 (91.4%)	118 (61.1%)
1	3 (6.25%)	6 (8.6%)	51 (26.4%)
≥2	0	0	24 (12.4%)
Gestational age at ultrasound (weeks)[a]	38.63 ± 1.18	38.89 ± 1.48	38.91 ± 1.30
Gestational age at delivery (weeks)[a]	38.8 ± 1.15	39.34 ± 1.32	39.26 ± 1.32
Delivery approach			
Elective CD[b]	37 (77.1%)	22 (31.4%)	88 (45.6%)
TOLAC[b]	11 (22.9%)	48 (68.6%)	105 (54.4%)
Outcome of TOLAC[b]			
Emergency CD	11 (22.9%)	23 (32.9%)	34 (17.6%)
Successful VBAC	0	25 (35.7%)	71 (36.8%)
Outcomes			
Number of uterine ruptures[b]	2 (4.2%)	0	0
Number of uterine defects (Scar dehiscence + rupture)[b]	11 (22.9%)	1 (1.4%)	0
Birthweight (kg)[a]	3.14 ± 0.54	3.16 ± 0.37	3.23 ± 0.44
Composite adverse maternal morbidity[b]	3 (6.3%)	10 (14.3%)	22 (11.4%)
Perinatal mortality[b]	3 (6.3%)	0	2 (1.0%)
Composite perinatal morbidity[b]	10 (20.8%)	8 (11.4%)	12 (6.2%)

Abbreviations: CD, caesarean delivery, TOLAC, trial of labour after previous caesarean; VBAC, vaginal birth after caesarean.

[a]Data are presented as mean ± SD.

[b]Data are presented as frequencies (%).

TABLE 2 Reasons for a failed TOLAC grouped according to their mLUS thickness.

mLUS thickness on ultrasound	Fetal distress (*n* = 27)	Cephalopelvic disproportion (*n* = 25)	Slow labour progression (*n* = 13)	Antepartum haemorrhage (*n* = 3)
≤2 mm	8 (29.6%)	1 (4%)	1 (7.7%)	1 (33.3%)
2.1–2.9 mm	4 (14.8%)	9 (36%)	8 (61.5%)	2 (66.7%)
≥3 mm	15 (55.6%)	15 (60%)	4 (30.8%)	0

univariate logistic regression did not show a statistically significant association between previous VBAC and a successful VBAC (odds ratio [OR] 1.55, 95% CI 0.82–2.94; $p = 0.178$). VBAC success rate increased with increasing mLUS thickness (OR 1.30, 95% CI 1.03–1.64; $p = 0.028$). Notably, no vaginal births occurred in mLUS ≤2 mm (0/11), whereas the success rate was 52.1% (25/48) in mLUS between 2.1 and 2.9 mm and 67.6% (71/105) in mLUS ≥3 mm. However, post-hoc sensitivity analysis of the subgroup of participants without a previous VBAC did not corroborate such findings (OR 1.56, 95% CI 0.91–2.69; $p = 0.105$). Similarly, no statistically significant association was found between VBAC success and participants with mLUS >2 mm (OR 1.12, 95% CI 0.88–1.43; $p = 0.365$). A further evaluation of the reason for a failed VBAC and LUS findings at surgery revealed 8/68 (11.8%) cases to be associated with a uterine defect, which included 5/8 (62.5%) cases of fetal distress, 2/8 (25%) cases of CPD and 1/8 (12.5%) case of slow labour progression.

Twelve cases of uterine defects (scar dehiscence and uterine rupture) were observed in our cohort, 11 (91.7%) of them had an ultrasound LUS ≤2 mm and one had a measurement of 2.8 mm. Out of this number, eight cases

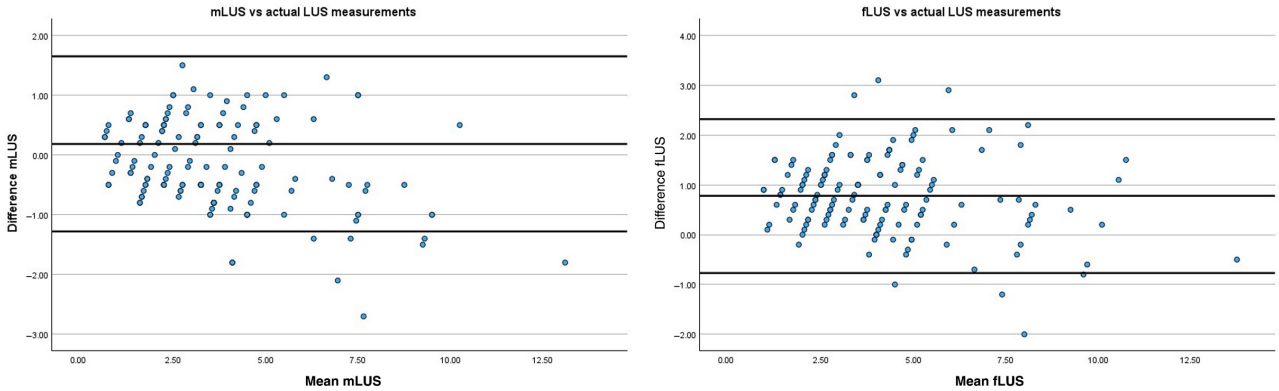

FIGURE 3 Bland–Altman plot depicting the comparability of the ultrasound measurements to the intraoperative measurements.

underwent an emergency CD because of a failed VBAC attempt, which included six cases of scar dehiscence and two cases of uterine rupture. The two cases of uterine rupture had mLUS ultrasound measurements of 1.9 and 2 mm. In the elective CD group, four cases of scar dehiscence were identified; three cases had LUS measurement ≤1 mm and one case had a LUS measuring 1.5 mm. Diagnostic test of accuracy for ultrasound LUS ≤2 mm in predicting uterine defect revealed an Aaea under the receiver operatiing characteristics curve of 0.867 (95% CI 0.77–0.96) with a sensitivity of 91.7% (95% CI 61.5–99.8) and specificity of 81.8% (95% CI 75.8–86.8).

No statistically significant difference was observed in the birthweight between the successful and failed VBAC ($p = 0.077$). However, the highest number of successful VBACs (43/96; 44.8%) occurred in the 3.1–3.5 kg weight range and this was followed by 34/96 (35.4%) in the 2.6–3.0 kg weight range. Maternal complications that arose from the successful VBAC group primarily consisted of perineal tears and postpartum haemorrhage. The composite measure of maternal adverse outcomes (consisting of postpartum haemorrhage, uterine rupture, haemoperitoneum, organ injury) for the emergency CD group were higher compared with the elective CD group ($p = 0.005$). However, this composite adverse maternal outcome showed no statistically significant difference between the successful VBAC and failed VBAC ($p = 0.547$). Five perinatal deaths occurred; three occurred in the intended VBAC group and two in the elective CD group. Within the VBAC group, two deaths occurred from intrapartum uterine rupture with the third being a result of a placental abruption; all these cases required emergency CD due to fetal distress. Two perinatal deaths occurred in the elective CD group, which were due to neonatal sepsis. The composite adverse neonatal outcome (consisting of neonatal sepsis, Apgar scores <7, death, meconium liquor (Grade 3) was significantly higher in the emergency CD group compared with the elective CD group ($p < 0.001$). Similarly, the composite neonatal outcome was higher in the failed VBAC group when compared with the successful VBAC group ($p = 0.005$).

4 | DISCUSSION

4.1 | Key findings

Our findings revealed that mLUS ultrasound measurements compared favourably with intraoperative measurements. There was greater agreement when intraoperative LUS thickness was <5 mm, compared to when the LUS was ≥5 mm. In contrast, fLUS ultrasound measurements were overestimated when intraoperative LUS thickness was <5 mm but were relatively comparable when the thickness was ≥5 mm.

The rate of successful VBAC increased with increasing ultrasound mLUS measurements with a 71/105 (67.6%) success rate in mLUS ≥3.0 mm, 25/48 (52.1%) success in measurements between 2.1 and 2.9 mm and no successful VBAC with mLUS ≤2 mm (0/11). Uterine defects (comprising scar dehiscence and uterine rupture) were found in 12 participants; 11 of these had LUS measurements ≤2 mm, while one had a measurement of 2.8 mm and a uterine scar dehiscence. Diagnostic test of accuracy for mLUS ≤2 mm in predicting uterine defect revealed an excellent sensitivity of 91.7% (95% CI 61.5–99.8%) and specificity of 81.8% (95% CI 75.8–86.8%).

4.2 | Clinical and future research implications

Previous studies have evaluated the impact of LUS measured by ultrasound in predicting VBAC success rate; however, there is a lack of robust evidence to support its inclusion in routine practice. Although meta-analyses published on the topic have shown promising findings,[19,20,37,38] the major difficulty in interpreting the data is heterogeneity in the ultrasound technique, which results in different cut-off values. In this study, we systematically reviewed the various ultrasound techniques and concluded that the 2D transvaginal technique was the most reproducible.

Our study demonstrated that TVUS measurements of the myometrial thickness compared favourably with the

intraoperative measurements, with higher degree of comparability in smaller LUS thickness (<5 mm). This observation is significant, given that concerns regarding morbidity in clinical contexts are predominantly associated with smaller LUS thickness. Our research further reveals that, an elevated risk of uterine scar defect is associated with mLUS thickness ≤2 mm, regardless of the intended mode of delivery, with a sensitivity of 91.7% (95% CI 61.5–99.8%) and specificity of 81.8% (95% CI 75.8–86.8%).

It is worth noting that, among the 12 cases of uterine scar defects observed within our series, 11 of them had mLUS measurements ≤2 mm. In similar studies, this pattern is upheld, as smaller LUS thickness on TVUS was associated with a higher risk of a scar defect.[37,39,40] In contrast to our study, Bujold et al.[34] favoured fLUS technique over mLUS in predicting uterine scar defect. However, the high comparability of mLUS with the actual intraoperative LUS thickness in small values (bias of 0.01 mm [95% CI −0.10 to 0.12 mm]) is a significant strength of this technique. The relatively higher bias observed with fLUS technique (bias of 0.93 mm, 95% CI 0.80–1.06 mm) could be attributed to the measurement approach, as it inadvertently includes the posterior urinary bladder wall as part of its measurement.[32] Hence, this measurement approach is prone to considerable influence by the extent of urinary bladder filling. The occurrence of uterine scar defect is a mechanical process resulting from the progressive stretching of the LUS by both uterine contractions and presenting fetal part (usually the head), hence thinner LUS are more likely to result in uterine defects. Considering the clinical implications of uterine defects, we believe that the ultrasound measurement technique with the least risk of bias should be considered. Some authors argue that the mLUS technique is more technically difficult and may be affected by the ultrasound settings.[37] However, just like any other obstetric ultrasound measurement techniques, such as nuchal translucency and fetal biometric measurements, the establishment of a standardised protocol and quality training programme with an effective audit process ensures accuracy and reduction of clinically significant errors.[41]

Our study demonstrated a statistically significant association between VBAC success rate and increasing mLUS measurements (OR 1.30, 95% CI 1.03–1.64; $p = 0.028$). However, a post-hoc sensitivity analysis did not find a statistically significant association between mLUS and VBAC success in those without a previous VBAC. Similarly, no statistically significant association was observed between previous VBAC and a successful VBAC (OR 1.55, 95% CI 0.82–2.94; $p = 0.178$). These findings reflect the daily occurrence in labour wards as successful vaginal births are often influenced by multiple fetal and maternal factors even outside the context of a uterine scar.

The success rate of VBAC in sub-Saharan Africa is reported to be 60–80%;[42] however, most of these studies were conducted in well-resourced tertiary centres and university hospitals so may not be replicable in secondary centres in the same region, where there may be inadequately skilled personnel and lack of equipment and blood products. Also, the definition for successful VBAC in most of these studies is vaginal delivery without accounting for other postpartum events such as postpartum haemorrhage necessitating blood transfusion and adverse outcome for the baby.[43] However, our research findings show that TVUS measurement of LUS thickness is possible in a limited-resource setting, and it demonstrates significant association with VBAC success and detection of uterine scar defects. Consequently, it could provide more information during counselling and shared decision-making on the preferred mode of delivery that has been proven effective in reducing major perinatal and maternal morbidity.[44-46]

For future studies, we recommend a randomised controlled trial with the incorporation of LUS with other obstetric parameters, such as estimated fetal weight, interpregnancy interval, previous successful VBACs, to determine a suitable bespoke algorithm for determining the best candidate for VBAC in a limited-resource setting. Considering the very close range of mLUS values and the clinical implications of borderline values (±0.1 mm), care must be taken by the sonographer to obtain the appropriate images, with repeat measurements in order to identify the thinnest LUS.

4.3 | Strengths and weaknesses

The strengths of this study lie in its methodological approach in attempting to determine the most appropriate sonographic technique for LUS measurement and assessing its accuracy compared with intraoperative findings. Several studies have published individual sonographic techniques and intraoperative assessment of the LUS. This study offers a comprehensive assessment of these sonographic techniques through literature review and evaluates how the two transvaginal LUS measurement techniques correlate with intraoperative findings. The attending obstetricians were blinded to the ultrasound findings and measurements, which limited the risk of bias.

The primary limitation to our research stems from the mid-protocol modification, which led to the exclusion of three enrolled participants with LUS ≤2 mm. This exclusion introduces bias into our study for the TOLAC group. Although statistically significant sample sizes are typically required to establish the effectiveness of an intervention (in this case LUS measurement), the lack of any successful VBACs for 11 women with a LUS of ≤2 mm demonstrated a much larger effect size than had been estimated. Given the five cases of dehiscence and intrapartum deaths of two babies from uterine rupture, we could not ethically advocate for subsequent mothers to proceed with their planned TOLAC if their LUS was ≤2 mm. We believe that this change to the protocol was appropriate on patient safety grounds and that the bias introduced was minimal. Despite the promising finding of an excellent sensitivity of LUS ≤2 mm, low incidence of

uterine defect 12/311 (3.8%) resulted in a wider confidence interval and hence it should be interpreted with caution. Also, all ultrasound measurements were undertaken by a single operator, so we could not ascertain the interoperator reliability of this technique.

5 | CONCLUSION

In summary, accurate measurement of LUS using TVUS in women with one previous CD is possible in low-income settings. Despite our promising findings, we acknowledge that the decision for selecting the best TOLAC candidate is always multifactorial, and we encourage obstetricians to consider a holistic approach in selecting a candidate for a TOLAC. Nevertheless, considering the 100% VBAC failure rate and high association of a LUS of ≤2 mm with uterine defects, we would discourage planning a VBAC in women with a LUS measurement ≤2 mm, especially in limited-resource settings where uterine rupture frequently results in perinatal mortality.

AUTHOR CONTRIBUTIONS

CAT conceived the study, supervised data collection and helped in drafting the manuscript; CAT and TAB reviewed the ultrasound techniques and methodology. TAB performed the ultrasound, drafted the manuscript and performed the statistical analysis. SC reviewed the methodology, results and analysis and supervised the structure of the manuscript. All authors contributed and finalised the manuscript.

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CONFLICT OF INTERESTS

None declared.

DATA AVAILABILITY STATEMENT

The data that support the study findings are available on request from the corresponding author.

ETHICS APPROVAL

Previous ethics approval was obtained from the Komfo Anokye Teaching Hopsital Institutional Review Board with reference number: (KATH IRB/AP/117/21). Ethical approval was obtained on 1 November, 2021. Written informed consent was obtained from patients before recruitment.

ORCID

Sally L. Collins https://orcid.org/0000-0002-0648-7433
Theophilus Adu-Bredu https://orcid.org/0000-0003-2365-6769

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SUPPORTING INFORMATION

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

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