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TRANSABDOMINAL EVALUATION OF UTERINE CERVICAL LENGTH DURING PREGNANCY FAILS TO IDENTIFY A SUBSTANTIAL NUMBER OF WOMEN WITH A SHORT CERVIX

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Abstract

Objective—To assess the diagnostic performance of transabdominal sonographic measurement of cervical length in identifying patients with a short cervix.

Methods: Cervical length was measured in 220 pregnant women using transabdominal and transvaginal ultrasound (US). Reproducibility and agreement between and within both methods were assessed. The diagnostic accuracy of transabdominal US for identifying cases with a cervical length <25mm was evaluated.

Results: Twenty-one out of 220 cases (9.5%) had a cervical length <25mm by transvaginal US. Only 43% (*n*=9) of patients with a short cervix were correctly identified by transabdominal US. In patients with a cervical length of <25mm by transvaginal US, transabdominal measurement of the cervix overestimated this parameter by an average of 8mm (95% LOAs: −26.4 to 10.5mm). Among women without a short cervix, transabdominal US underestimated cervical length on average (LOA) by 1.1mm (95% LOAs: −11.0 to 13.2mm). Transvaginal US was also more reproducible (intraclass correlation coefficient: (ICC: 0.96; 95% CI: 0.94 to 0.97) based on comparisons between 2D images and immediately acquired 3D volume datasets relative to transabdominal US (ICC: 0.71; 95% CI: 0.57 to 0.84). Transvaginal US detected 13 cases with funneling and 6 cases with sludge whereas only 3 cases of funneling and one of sludge were detected by transabdominal US.

Conclusion: Transabdominal measurement overestimated cervical LOA by 8mm among women with a short cervix and resulted in the underdiagnosis of 57% of cases.

Keywords

ultrasound; agreement; preterm labor; screening; progesterone; progestins

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Introduction

Sonographic cervical length is a powerful method to identify patients at risk for preterm delivery (1–9). The shorter the cervix, the greater the risk for preterm delivery (10–18). Patients with a cervical length <15mm have an approximate 50% likelihood of preterm delivery <32 weeks, regardless of risk factors (19,20). Moreover, it is possible to calculate the individual risk for preterm delivery based on cervical length and other patient characteristics (21).

A short uterine cervix during pregnancy is syndromic in nature and can be the consequence of congenital factors (22–25), prior surgery of the uterine cervix (26–28), subclinical intra-amniotic infection/inflammation (29–36), an entity clinically referred to as cervical insufficiency (37–39), or due to a suspension of progesterone action (40). Therapeutic interventions for patients with a short cervix include cervical cerclage (41,42), cervical pessary (43,44) and the administration of vaginal progesterone (45–54). Vaginal progesterone has emerged as an effective therapy to prevent preterm delivery in women with a short cervix in the midtrimester of pregnancy. This intervention also reduces admission to the newborn intensive care unit, respiratory distress syndrome, the requirement for mechanical ventilation, and composite neonatal morbidity and mortality score (54).

While transvaginal ultrasound (US) is considered the "gold standard" for the diagnosis of a short cervix during pregnancy, and its advantages in terms of accuracy and acceptability for patients have been previously described (55–66), several investigators continue to propose that transabdominal cervical length assessment can be used to identify patients with a short cervix. For example, Saul et al. (67) reported that transabdominal sonography had a 100% sensitivity in detecting a short cervix defined by transvaginal sonography (<25mm). The cut-off used for transabdominal US was a cervical length <30mm. Stone et al. (68) also proposed that transabdominal US measurement of cervical length could be the primary method for identifying patients with a short cervix.

To address the relative accuracy of transabdominal and transvaginal sonography in the detection of a short cervix during pregnancy, we compared endocervical length obtained by both methods.

Materials and Methods

Patients

Two hundred and twenty consecutive pregnant women with a singleton gestation were evaluated at Hutzel Women's Hospital of the Detroit Medical Center from May to August 2011. All patients provided written informed consent before the US examination. The collection of data for research purposes was approved by the Institutional Review Boards of the Wayne State University School of Medicine and the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, NIH, DHHS.

Sonographic Examination

All sonographic examinations were performed using Voluson E8 (GE Healthcare, Milwaukee, WI, USA); Acuson Sequoia (Siemens Medical Systems, Malvern, PA, USA), or Philips iU22 (Philips Healthcare, Bothell, WA, USA) equipment. Three-dimensional (3D) US volumes were obtained only using Voluson E8, and volumetric evaluations performed using 4D View software (GE Healthcare, Milwaukee, WI, USA).

Cervical length was first measured by transabdominal US, with the patient in the supine position and with a full bladder. If the bladder was not sufficiently full to provide an acoustic window, the examination was delayed until visualization of the cervix was achieved. The cervix was identified in the mid-sagittal plane and cervical length was measured by placing the calipers at each end of the endocervical canal (Figure 1a). In 75 patients, an additional transabdominal 3D sonographic volume of the cervix was obtained using an angle of 95°, a fast acquisition and adjusting the sample box to include the entire cervix. The acquisition plane was a mid-sagittal scan.

A transvaginal US was performed by a different operator, blinded to the results of the transabdominal measurement. Patients had an empty bladder for this examination. Cervical length was measured in a mid-sagittal plane from the internal to the external os using methods previously described (Figure 1b). In 100 cases, a 3D US cervical volume was recorded using the sagittal plane as the starting point of acquisition. The presence/absence of funneling and sludge was documented during each examination. The criteria proposed by Burger et al. (69) was used to standardize endocervical canal biometry and examination of the uterine cervix.

Each cervical volume dataset was evaluated by an individual who had not performed the US examination. Multi-planar reformatting was used to select the plane for measurement. In volumes obtained transabdominally and transvaginally, the cervix was displayed in the sagittal plane in quadrant A, the transverse plane in quadrant B and the coronal plane in quadrant C. The optimal plane of measurement was identified by scrolling in quadrants A and C. The image was rotated on the X, Y or Z axis and the size adjusted to obtain the best image of the cervix which displayed the entire endocervical canal.

Statistical methods

The interclass correlation coefficient and the 95% limits of agreement (LOA) were calculated when comparing transabdominal to transvaginal cervical length measurements (70). The sensitivity of transabdominal US to detect a short cervix (< 25mm by transvaginal US) was calculated. Measurements of the endocervical canal obtained by transvaginal US were considered the "gold standard". The frequency with which each method identified sludge and funneling was recorded.

Reproducibility was measured via a modified intraclass correlation coefficient, calculated among 2D and 3D measurements; this is a `modified' indicator because two separate measurements were not obtained. Rather, a 3D volume dataset was acquired immediately following the 2D measurement, meaning that the ultrasound probe was not removed and reinserted to obtain a "true" second measurement. This was done for pragmatic reasons, and to decrease any additional discomfort for patients.

Normality of the data distributions was assessed using the Kolmogorov-Smirnov test and inspection of histograms and quantile-quantile (Q-Q) plots. Mean and median differences in cervical length measurements were assessed by parametric (paired *t*-test) and non-parametric (Wilcoxon Rank Sum) tests. A linear mixed model with random effects model was used to account for the paired repeated measures design and, additionally, to adjust for gestational age at time of measurement when comparing transvaginal and transabdominal cervical length measurements. An effect modification term was used to determine whether transvaginal measurements differed from transabdominal by whether the patient had a short cervix as determined by transvaginal US; stratified models were used to illustrate the effect modification. Measurements obtained using 2D relative to 3D US acquired volume datasets were similarly evaluated as an indicator of reproducibility. A p-value of < 0.05 was considered significant. Statistical analyses were conducted using SAS statistical analysis software version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

The median maternal age at the time of the study was 23 years (range: 16–41 years); gestational age (median: 24 3/7 weeks; range: 6 2/7 – 39 weeks) and; number of previous pregnancies (median: 1; range: 1–4). The prevalence of a short cervix (length <25mm) was 9.5% (21/220) as determined by transvaginal sonography.

Accuracy of Transabdominal versus Transvaginal Ultrasound (US)

Descriptive statistics of cervical length measurements obtained by the two methods are summarized in Table I. While transabdominal cervical length measurements were normally distributed, cervical length measurements obtained transvaginally departed from normality (Kolmogorov-Smirnov Test $p<0.01$). Inspection of histograms and Q-Q plots suggested transvaginal cervical measurements departed only slightly from normality; accordingly, we conducted both parametric and non-parametric tests in assessing differences in cervical length measurements by method.

Overall, there was moderate correlation between transabdominal and transvaginal cervical length measurements (r = 0.49; 95% CI = 0.39 to 0.56). The 95% LOAs between transvaginal and transabdominal cervical length measurements ranged from −13.5 to 14mm (mean difference 0.2mm). Both parametric and non-parametric tests indicated that overall mean/median cervical length measurements were similar when examined as continuous variables and determined with either method ($p=0.62$, $p=0.30$, respectively). Adjustment for the paired design, and further, for gestational age at time of examination, did not alter this association ($p=0.63$); however, cervical length measurements differed significantly by method with respect to the diagnosis of a short cervix ($p<0.001$).

Among patients with a cervical length <25mm by transvaginal US, a systematic overestimation of cervical length by transabdominal US was observed (mean difference, 8mm; 95% LOAs: −26.4 to 10.5mm). Among women without a short cervix, transabdominal ultrasound underestimated cervical length on average by 1.1mm (95% LOAs: −11.0 to 13.2mm) (Figure 2). Both parametric and non-parametric tests indicated that the mean/median cervical length measurements obtained via transvaginal US were significantly lower than those obtained by transabdominal US among women with a short cervix ($p<0.001$ for both); adjustment for the paired design, and further, for gestational age at time of examination, did not alter this association ($p<0.001$). Among women without a short cervix, both parametric and non-parametric tests revealed significant mean/median differences in cervical length ($p=0.002$, $p=0.01$ respectively). However, as indicated in Table II, the direction of effect was reversed among patients with transvaginally determined cervical lengths > 25mm, meaning transabdominal measurements were systematically shorter than transvaginal measurements ($p=0.01$), although the mean difference did not appear to be clinically significant.

Transabdominal cervical length was able to identify only 43% (9 of 21) of patients with a short cervix (cervical length < 25mm by transvaginal US); in the remaining 12 patients, transabdominal US overestimated the cervical length on average by 14mm (range: 5.6 to 26mm). If a 30mm cut-off had been used to screen women for a short cervix transabdominally in our study, only 3 of 12 missed cases would have been detected. Further, while transvaginal US detected 13 cases with funneling and 6 cases with sludge, only 3 cases of funneling and one of sludge were detected by transabdominal US. There were no cases in which funneling or sludge were observed by transabdominal US, but not by transvaginal US.

Reproducibility: 2D versus 3D measurements

Transvaginal measurements were more reproducible based on comparisons between 2D images and immediately acquired 3D volume datasets (intraclass correlation coefficient: 0.96; 95% CI: 0.94 to 0.97) compared to transabdominal measurements (intraclass correlation coefficient: 0.71; 95% CI: 0.57 to 0.84). Greater agreement was also observed among measurements obtained transvaginally (95% LOAs: −5.1 to 5.0mm; mean difference 0.2mm) than transabdominally (95% LOAs: −10.1 to 13.1mm; mean difference 1.3mm) (Figure 3). The mean/median differences between 2D and 3D volume measurements were marginally statistically significant (p=0.17, p=0.08, respectively); differences among Transabdominal measurements were greater than those among transabdominal transvaginal measurements.

Discussion

Principal findings of this study

This study shows that:

1. Transabdominal US measurement of cervical length was unable to identify 57% of cases with a short cervix (<25mm) as determined by transvaginal US;
2. The accuracy of transabdominal US differed significantly according to whether a patient had a short cervix or a normal cervical length;
3. Transabdominal US systematically overestimated cervical length relative to transvaginal US among women with a short cervix (mean difference: 8mm; 95% LOAs: −10.5 to 26.4mm);
4. Among women with a short cervix, transabdominal US underestimated cervical length relative to transvaginal US;
5. Transvaginal US is more reproducible based on comparisons between 2D images and immediately acquired 3D volume datasets relative to transabdominal US; and
6. Transabdominal US did not detect funneling and sludge in all cases.

Potential implications for identification of women at risk for preterm delivery

Preterm birth is the leading cause of perinatal morbidity and mortality worldwide (71–77). In the United States, the cost of preterm birth has been estimated to be $26 billion annually (2005 dollars), and survivors are at a significantly greater risk of complications including asthma or reactive airway disease, cerebral palsy, developmental delays, autism, and behavioral/emotional disorders than infants born at term (78–94).

Cahill et al. (95) evaluated different strategies to reduce the rate of preterm delivery, including identifying patients at risk according to a previous history, by sonographic examination of the cervix, and treatment modalities, including cervical cerclage, 17-hydroxyprogesterone caproate and vaginal progesterone. Among different strategies, the authors concluded that universal assessment of cervical length with transvaginal sonography followed by vaginal progesterone administration was the most cost-effective approach (95). Similarly, Werner et al. (96) concluded that universal cervical screening and vaginal progesterone administration to women with a short cervix will lead to a cost savings of $19 million per 100,000 pregnant women or more than $500 million per year in the United States alone (96).

How should cervical examination be performed to assess the risk of preterm delivery?

Historically, cervical examination was first performed with transabdominal sonography (and subsequently with transperineal sonography), but eventually transvaginal US became the "gold standard" (97–101). Visualization of the cervix with transabdominal sonography requires a full maternal bladder to provide an acoustic window to visualize the endocervical canal, internal cervical os and external os (100). Despite a full bladder, clear definition of the anatomical landmarks is not always possible (102,103). Therefore, Robinson et al. (104) subsequently proposed the placement of a saline solution in the vagina to improve the definition of the ectocervix; however, this approach is not optimal for patients.

Bladder size also contributes to the variability of measurements obtained transabdominally: while a full bladder allows better visualization of the cervix (105), it can also affect the identification of the landmarks for measurements, and artificially increase the cervical length due to overdistension (100,106). To et al. (107) reported that the size of the bladder can affect the visualization of the cervix; when the urine volume was <50ml, the cervix was visualized in only 42% of women. There is also evidence that transabdominal US may be associated with greater discomfort than transvaginal examination. Braithwaite et al. (108) reported that while 3.8% of women reported marked discomfort with transabdominal US, while only 0.7% of women reported the same when examined by transvaginal US.

Transvaginal US measurements are affected by the degree of pressure applied with the US transducer to the cervix which can slightly change the orientation and measurements. Maternal age, uterine contractions and cervical dynamic changes can also affect the measurement (113–116). Londero et al. (113) reported that women younger than 20 years of age had longer cervices than older women, and Meijer-Hoogeveen et al. (114) reported that uterine contractility and bowel peristalsis can modify cervical length by up to 5mm.

We undertook this study because we were surprised that some investigators continue to propose that transabdominal sonography can be used to screen patients to detect those with a short cervix (67,68). This strategy had been used in the past in certain units to reduce the number of transvaginal examinations performed. However, this was at the expense of accuracy in cervical length determination, patient comfort (i.e. transabdominal sonography requires a full maternal bladder for optimal visualization, which is uncomfortable and represents a challenge in managing the waiting room of an US unit), and time management efficiency for patients and health care personnel. Our data clearly indicates that screening with transabdominal US for a short cervix would underdiagnose this condition and deny patients the opportunity to benefit from vaginal progesterone administration. Although it can be argued that the US examination can be repeated, this would add cost to the healthcare system from the subsequent visits, and may also decrease the effectiveness of therapy because treatment would begin when the process of cervical ripening and shortening is more advanced.

An interesting observation of this study is that when the cervix was short (<25mm), transabdominal sonography failed to detect 57% of the cases, and the cervical length was overestimated with the transabdominal approach. This was not the case when the cervix was long. Why? One explanation is that when cervical ripening occurs, the cervix is more compliant (106,115,116). Consequently, a distended maternal bladder (required for transabdominal sonography) could lengthen the cervix to a greater extent than when the cervix is not ripe (or longer). This interpretation is consistent with an observation that there is not a substantial difference in transabdominal and transvaginal US in which cervical ripening does not occur (117).

Limitations of this study

Reproducibility was not assessed using truly separate measurements, although our finding of greater reproducibility using transvaginal US is consistent with previous reports (55,56,118,119). Our results may also be specific to our population; however, it is unlikely that demographic patient characteristics have an effect on the results of cervical length using different approaches. One of the limitations of this study is that the number of patients with sludge was small (n=6), and therefore, the sample size is inadequate to test the sensitivity of transabdominal sonography in the detection of sludge. This important sonographic sign was initially described with transvaginal sonography (120,121), and there is no evidence that transabdominal sonography has a comparable diagnostic value. Indeed, the high frequency transducers used for transvaginal sonography produces images of the cervix and the amniotic fluid in direct proximity to the endocervical canal that are consistently superior to those of transabdominal transducers.

Conclusion

Our study indicates that transabdominal US systematically overestimates endocervical length among women with a short cervix. This approach missed 57% of short cervices in our study. Therefore, we conclude that transabdominal US is not appropriate to identify the patients who should have a subsequent transvaginal US to diagnose a short cervix. Our observations suggest that if one of the goals of US examination is to identify patients with a short cervix, transvaginal US should be used as the primary method for measuring the endocervical canal. Otherwise, clinicians are at risk for underdiagnosing not only a short cervix, but also the presence of cervical changes, such as sludge, which are less well-visualized with transabdominal US. The presence of sludge has prognostic value above that provided by cervical length alone. This sign cannot be reliably identified with transabdominal sonography. This has clinical implications because patients with sludge are at greater risk for intra-amniotic infection/inflammation (121). The under-diagnosis of a short cervix would result in denying effective and safe therapy for the prevention of preterm birth for a substantial number of patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table I

Descriptive statistics of the cervical length measurement (mm) performed by transabdominal and transvaginal ultrasound.

Descriptive statistics	Transabdominal	Transvaginal
Mean	34.6	34.8
SD	7.55	6.99
Percentiles:		
5	23	21.6
10	26.5	25.9
25	30.5	31.6
50	34.8	36.1
75	38.8	39.1
90	43.3	42.7
95	46.3	44

SD = standard deviation.

Table II

Differences in cervical length by ultrasound method in the complete study group and stratified by short cervix as determined transvaginally.

Ultrasound Method	All studied Population mm, mean (SD)	Cervical Length mean (SD)	
		<25mm	>25mm
Transabdominal	34.57 (7.1)	26.6 (9.2)	35.2 (6.4)
Transvaginal	34.81 (6.9)	20.1 (3.8)	36.4 (5.2)
Significance	p=0.61	p<0.001	p<0.01

SD = standard deviation