Mid-Trimester Endovaginal Sonography in Women at High Risk for Spontaneous Preterm Birth

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Preterm birth is the most important cause of infant morbidity and mortality and complicates 11% of all pregnancies in the United States. Most (80%) of these births result from either spontaneous labor or membrane rupture. Since the development of neonatal intensive care units, most neonatal deaths associated with prematurity occur in infants born at less than 32 weeks' gestation, but significant morbidities including sepsis, respiratory distress, and necrotizing enterocolitis do not abate until 35 weeks' gestation, after which neonatal outcomes are generally good. To date, a prior preterm birth is one of the strongest and most consistent predictors of prematurity, and the risk of recurrence is inversely proportional to the gestational age of the prior delivery.

Context Although shortened cervical length has been consistently associated with spontaneous preterm birth, it is not known when in gestation this risk factor becomes apparent.

Objective To determine whether sonographic cervical findings between 16 weeks' and 18 weeks 6 days' gestation predict spontaneous preterm birth and whether serial evaluations up to 23 weeks 6 days' gestation improve prediction in high-risk women.

Design, Setting, and Participants Blinded observational study performed between March 1997 and November 1999 at 9 university-affiliated medical centers in the United States in 183 women with singleton gestations who previously had experienced a spontaneous birth before 32 weeks' gestation.

Observation Certified sonologists performed 590 endovaginal sonographic examinations at 2-week intervals. Cervical length was measured from the external os to the functional internal os along a closed endocervical canal. Funneling and dynamic cervical shortening were also recorded.

Main Outcome Measure Spontaneous preterm birth before 35 weeks' gestation, analyzed by selected cutoff values of cervical length.

Results Forty-eight women (26%) experienced spontaneous preterm birth before 35 weeks' gestation. A cervical length of less than 25 mm at the initial sonographic examination was associated with a relative risk (RR) for spontaneous preterm birth of 3.3 (95% confidence interval [CI], 2.1-5.0; sensitivity = 19%; specificity = 98%; positive predictive value = 75%). After controlling for cervical length, neither funneling (P = .24) nor dynamic shortening (P = .054) were significant independent predictors of spontaneous preterm birth. However, using the shortest ever observed cervical length on serial evaluations, after any dynamic shortening, the RR of a cervical length of less than 25 mm for spontaneous preterm birth increased to 4.5 (95% CI, 2.7-7.6; sensitivity = 69%; specificity = 80%; positive predictive value = 55%). Compared with a single cervical measurement at 16 weeks' to 18 weeks 6 days' gestation, serial measurements at up to 23 weeks 6 days significantly improved the prediction of spontaneous preterm birth in a receiver operating characteristic curve analysis (P = .03).

Conclusions Cervical length assessed by endovaginal sonography between 16 weeks' and 18 weeks 6 days' gestation, augmented by serial evaluations, predicts spontaneous preterm birth before 35 weeks' gestation in high-risk women.

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Endovaginal ultrasound is a reliable technology for imaging the cervix and lower uterine segment during pregnancy. While there is ample evidence that a shortened cervical length is associated with preterm birth, it
is not known when this risk factor becomes apparent in pregnancy or whether the adverse cervical ultrasound findings develop over time. Moreover, most of the current data linking cervical length to subsequent preterm birth have been collected beyond 20 weeks’ gestation.12,17-19 Importantly, most of the available data have been collected either in unselected, low-risk populations11,13,14,16 or without physician masking, which means interventions were applied on the basis of the sonographic findings without a control group for comparison,14,15,17,18 thus rendering the predictive value of the cervical sonographic findings uncertain. The importance of longitudinal observations and the natural history of cervical characteristics in the mid-trimester have also not been well defined.12,17-19

Our objective was to determine whether cervical characteristics visualized with endovaginal sonography as early as 16 weeks’ through 18 weeks 6 days’ gestation or longitudinally up to 23 weeks 6 days’ gestation would predict spontaneous preterm birth in women with a previous spontaneous preterm birth before 32 weeks’ gestation. From the standpoint of efficacy and other biological considerations, certain interventions (cerclage) might be more effective if applied early in gestation (ie, before 24 weeks). We hypothesized that endovaginal sonography could identify women whose cervical anatomy would make them candidates for future mid-trimester clinical intervention trials of preterm birth prevention.

METHODS
This study was performed at 9 university-affiliated centers, all members of the National Institute of Child Health and Development, Maternal-Fetal Medicine Units Network, between March 1997 and November 1999. Women with singleton pregnancies who had experienced at least 1 prior spontaneous preterm birth before 32 weeks’ gestation were eligible; funding was not available to study a concurrent, low-risk control population. If obstetric records were not available, a history consistent with spontaneous preterm birth (preterm labor or membrane rupture) and a birth weight of less than 1500 g were deemed satisfactory criteria. Women with chronic medical or obstetric problems that might result in an indicated preterm birth (eg, hypertension, red blood cell isoimmunization), a history of substance abuse, or uterine anomalies were ineligible. Women who received a cerclage because of a clinical history of cervical incompetence were also excluded. The institutional review board at each center approved the study and potential participants who gave written, informed consent could be enrolled as long as their first endovaginal sonogram would be performed between 16 weeks’ and 18 weeks 6 days’ gestation.

Gestational age was determined by comparing a certain last menstrual period (if available) with a sonographic evaluation at or before 18 weeks’ gestation. Concordance between the biometric parameters and the menstrual date of 7 days or less confirmed the last menstrual period; otherwise, the biometric data were used. After the initial endovaginal sonographic evaluation, bi-weekly visits were scheduled to end no later than 23 weeks 6 days’ gestation with a maximum of 4 sonograms per patient.

Techniques
All sonograms were performed by physicians, ultrasound technologists, or research nurses who received uniform training and certification before patient enrollment. Each sonologist reviewed a training videotape of 8 complete mid-trimester endovaginal sonograms that demonstrated all the required measurements and subjective assessments. The videotape was accompanied with a detailed written description of each examination. Each sonologist independently performed 10 endovaginal examinations on unselected patients in the mid-trimester. The primary investigator critiqued the videotapes and accompanying data sheets to identify deficiencies. When necessary, the sonologist was asked to submit additional taped examinations and data sheets demonstrating correction of any previously identified deficiencies. From the videotaped examinations, the primary investigator also approved the ultrasound unit(s) at each center.

Each sonographic examination was performed according to a defined protocol: patients were asked to empty their bladder and then placed in a dorsal lithotomy position. The endovaginal probe covered by a sterile, lubricated condom was inserted and advanced along the vaginal canal until an adequate sagittal image of the cervix could be visualized. The probe was withdrawn slowly until the image blurred and then the insertion pressure was increased only enough to restore an adequate image.11,20 An adequate image for the measurement of cervical length was defined as the visualization of the internal os, external os, and endocervical canal.20

Cervical length was measured with electronic calipers as the linear distance between the external os and the functional internal os along a closed endocervical canal (Figure 1). However, if the endocervical canal appeared to be curved, cervical length was also assessed as the sum of the lengths of 2 contiguous linear segments, placed
along the endocervical canal, connecting the external os and functional internal os. If the maximum deflection of canal curvature (defined as the distance between a line connecting the internal os and external os and the maximum excursion of the 2 linear components) was at least 5 mm, the recorded cervical length measurement was the sum of the 2 linear segments (FIGURE 2A); otherwise, the single linear distance measurement was recorded (FIGURE 2B).

Cervical length measurements were performed 3 times. The sonologist assessed the overall quality of the 3 images and recorded the cervical length associated with the image that in his/her opinion was associated with the subjectively best image. However, if the cervical length differed on images of similar overall quality, the shortest observed cervical length was recorded. It was noted that a normal-appearing internal os could not be visualized as a discrete structure. This subjective diagnosis was characterized by the presence of an unusually long cervix (generally >50 mm), an s-shaped endocervical canal, an increased distance between the bladder reflection and the amniotic cavity, and 2 different echogenic areas in the cervix, and an apparent internal os located appreciably cephalad to the inferior edge of the bladder reflection. For analyses of cervical length as a continuous variable, cases of poorly developed lower segments were arbitrarily assigned a cervical length of 62 mm, which was 1 mm greater than the longest measured cervical length (61 mm).

A poorly developed lower uterine segment precluded a cervical length measurement because the internal os could not be visualized. According to the study protocol, the results of each scan were not made available to the patient’s managing physicians, except in cases of complete placenta previa (placental tissue visualized extending >1 cm on both sides of the internal os) or fetal death. The reason for any notification was recorded. As part of continuing quality assurance, a sample of the videotaped examinations was selected from each participating center proportional to its enrollment. The videotapes and data sheets were reviewed by the primary investigator in conjunction with another subcommittee member blinded to the pregnancy outcome. If any measurements or subjective assessments were deemed incorrect, the responsible sonologist and study coordinator were notified and asked to reexamine.

Figure 2. Sagittal Views of Endovaginal Sonograms of the Cervix at 18 Weeks’ Gestation

A, Normal-appearing cervix, note cervical length of 40 mm (the sum of the 2 linear segments, 28 mm and 12 mm) as the maximum canal deflection is 6 mm. Inferior extent of bladder reflection is approximately at the same level as the internal os. B, Cervix with funneling at the internal os, cervical length measured from external os to functional internal os is approximately 23 mm. Note asymmetric anterior and posterior “shoulders” cephalad to the internal os. Electronic calipers mark the endocervical canal. Tick marks visible along the top of both images represent a 1-cm scale.

Figure 2.
ine the videotape and make appropriate corrections. Initially, examinations were chosen at random. However, with increasing experience we also developed criteria for selected reviews that included all cases of funneling, cervical lengths less than 20 mm or greater than 50 mm, poorly developed lower uterine segments, spontaneous or funnel pressure–induced dynamic changes, and cases in which the physician was notified.

Data Analysis

The primary outcome criterion for this study was a spontaneous preterm birth before 35 weeks’ gestation, defined as a birth that resulted directly from either preterm labor or spontaneous membrane rupture before the onset of labor. Deliveries effected for maternal or fetal reasons were coded as indicated. As part of the study design, we performed a sample size calculation based on the following assumptions. Since appropriate mid-trimester sonographic pilot data were unavailable, sample size was based on data from the Preterm Prediction Study,11 which collected endovaginal sonographic data at both 24 weeks’ and 28 weeks’ gestation. We assumed the following: spontaneous preterm birth rate before 35 weeks for high-risk women with a cervical length of 25 mm or greater would be 10%; a cervical length less than 25 mm would occur in 20% of women; and the incidence of spontaneous preterm birth before 35 weeks would be 30%. Considering also a desired effect size of a relative risk (RR) of 3.0 for spontaneous preterm birth before 35 weeks (based on the presence or absence of a cervical length of <25 mm, 2-tailed α = .05, β = .20), 170 patients would have to be studied.

Data were analyzed using SAS version 7.0 (SAS Institute Inc, Cary, NC). Categorical variables were compared using χ² or the Fisher exact test, and continuous data were compared with the Wilcoxon rank sum test. Logistic regression was used to model the relationship between cervical length and spontaneous preterm birth controlling for funneling, recognition of dynamic shortening, and the slope of cervical length over time on serial evaluations (as derived from linear regression models). Receiver operating characteristic curves were used to compare the performance of varying cervical length cutoffs for the prediction of spontaneous preterm birth before 35 weeks. Statistical significance was represented at P < .05.

Since serial examinations were performed, we also compared spontaneous preterm birth either with cervical length at the initial examination or the shortest cervical length observed at any examination. Similarly, we analyzed cervical length before and after any dynamic shortening occurred. Thus, for any given patient, up to 4 different cervical lengths could be analyzed: (1) the length at the initial evaluation before dynamic shortening; (2) the initial length after dynamic shortening and considering the serial evaluations; (3) the shortest observed length before dynamic changes; and (4) the shortest observed length after dynamic shortening.

RESULTS

From all the participating centers, 236 women were initially thought to be eligible for this study based on their stated obstetric history. A total of 24 patients were found to be ineligible on review of their records. An additional 19 patients declined to participate, plus 6 more patients verbally agreed to participate but did not keep their first sonogram appointment and therefore were not enrolled. We did not collect outcome data on these 25 women who were eligible but not enrolled. From the original enrollment of 187, 4 patients were excluded because they were lost to follow-up.

A total of 590 endovaginal sonographic examinations were performed on our study population of 183 women between March 1997 and July 1999. The median duration of the sonographic examinations was 5.3 minutes (range, 4-18 minutes) and the median number of scans per patient was 3 (range, 1-4). Nine of the 183 women underwent a single sonographic evaluation. Of these 9, 3 delivered within 2 weeks of their first scan, before their next scheduled study visit. Of the 590 sonographic evaluations, 576 (98%) were videotaped according to protocol, and 466 (79%) of the taped examinations were later reviewed. After study inception, 4 women received a cerclage by their managing physicians. The 183 women in the study had a mean maternal age of 26 years (SD, 5 years); 119 (65%) were African American, 26 (14%) were white, and 38 (21%) were Hispanic. The earliest prior delivery occurred at a mean of 24 weeks’ gestation; 125 (68%) prior preterm birth, 37 had 2 prior preterm births, and 10 had more than 2 prior preterm births. On review, we determined that 1 patient had not experienced a prior spontaneous preterm birth before 32 weeks but, rather, had experienced an indicated preterm birth.

The mean gestational age at delivery was 35.2 weeks (SD, 6.3 weeks). A total of 48 (26%) women experienced a spontaneous preterm birth before 35 weeks; 35 (19%) before 32 weeks; 29 (16%) before 28 weeks; and 20 (11%) before 24 weeks. An additional 5 women underwent an indicated preterm delivery at 31 weeks’ to 34 weeks’ gestation for obstetric complications. Of the 48 spontaneous births before 35 weeks, 34 (71%) were associated with preterm labor and 14 (29%) were associated with preterm membrane rupture.

Initial Sonographic Evaluation

A total of 29 women (16%) had a poorly developed lower uterine segment throughout their entire initial evaluation. Since these women had been arbitrarily assigned a cervical length of 62 mm, the median baseline cervical length at the first scan was 37 mm (range, 0-62 mm); the 10th percentile was 26 mm and the 5th percentile was 23 mm. The relationship between cervical length at the initial evaluation and spontaneous preterm birth before 35 weeks was modeled with logistic regression. Women with shorter cervical lengths...
had correspondingly higher rates of spontaneous preterm birth before 35 weeks (P<.001). From the regression model, we determined that the odds of spontaneous preterm birth before 35 weeks decreased by 24% for each 5-mm increase in baseline cervical length. We then examined various cervical length cutoffs for their predictive accuracy (Table 1).

Since we had arbitrarily assigned a numeric cervical length value to women with a poorly developed lower uterine segment, we evaluated separately the predictive value of this finding. Of the 29 women with a poorly developed lower uterine segment throughout their initial evaluation, only 3 (10%) experienced a spontaneous preterm birth before 35 weeks compared with a 29% rate if the lower uterine segment was not poorly developed (P = .03).

In 9 cases, the sonologist notified the managing physicians after the sonogram had been performed. A total of 5 of these 9 cases were suspected placenta previa and were reported according to study protocol. However, in the other 4 cases, the protocol was not followed. Three were due to specific cervical findings (cervical bending, funneling, and internal os dilation) and in 1 case, the physician requested that the cervical length measurement be unmasked. Considering the potential for bias associated with physician notification and the 1 patient who had not previously experienced a prior spontaneous preterm delivery, we determined the effect of omitting these 10 women from the analysis of the initial sonographic evaluation. The RR for cervical length less than 25 mm and spontaneous preterm birth before 35 weeks (56% vs 23%; P = .004). However, women with an observed funnel also had a significantly shorter cervical length (median, 26 mm vs 38 mm if no funnel was observed; P<.001).

Because cervical length was such a strong predictor of spontaneous preterm birth before 35 weeks, we also evaluated the finding of a funnel as a potential independent predictor. The presence of a funnel was not a significant independent predictor, controlling for cervical length in a logistic regression model (P = .24). We also included either the presence of funneling or a cervical length cutoff of less than 25 mm in a contingency table with spontaneous preterm birth before 35 weeks and observed a lower RR of 2.7 (95% confidence interval [CI], 1.7-4.3) and a lower positive predictive value of 59% than when we used an isolated cervical length cutoff of less than 25 mm (Table 1).

Dynamic Changes
During their first sonographic evaluation, 16 (9%) of 183 women had observed dynamic changes. A total of 9 followed fundal pressure and 7 were spontaneous. The cervical lengths of these 16 women shortened from a mean of 49 mm (median, 62 mm) to a mean of 30 mm (median, 25 mm); 2 of these women also developed a funnel. In 6 cases, the initially observed, poorly developed lower uterine segment resolved. Similar to our analysis of funneling, we included dynamic changes in a logistic regression model with cervical length and observed a trend toward dynamic changes as a significant independent predictor of spontaneous preterm birth before 35 weeks (P = .054).

We also considered dynamic changes in a contingency table with a cervical length cutoff of less than 25 mm and spontaneous preterm birth before 35 weeks. As with funneling, the inclusion of dynamic changes at the initial evaluation did not improve the predictive accuracy of a cervical length cutoff of less than 25 mm (RR, 2.4; 95% CI, 1.5-3.8; positive predictive value, 52%).

Serial Evaluations
Serial evaluations demonstrated that cervical length shortened from a median of 37 mm at the first scan to a median of 32 mm at the fourth scan. For each of the 174 women with at least 2 sonographic evaluations, we computed the rate of change of cervical length by fitting a linear regression line to their observed cervical length measurements. The median rate of shortening in this group was 1.1 mm per week. Removing the 41 women who had a poorly developed lower uterine segment and therefore an assigned cervical length of 62 mm at any time during their initial and serial evaluations, we observed a median cervical length shortening of 0.9 mm per week. The 44 women who experienced a spontaneous preterm birth before 35 weeks shortened their cervixes at a median rate of 2.5 mm per week compared with a rate of 1.0 mm per week in the 130 women who did not (P = .03).

To determine the effect of serial observations on the predictive accuracy of endovaginal sono-
gression model with spontaneous preterm birth before 35 weeks as the dependent variable. In this analysis, the shortest ever observed cervical length before dynamic changes was a significantly better predictor than the baseline cervical length at the first scan. We further analyzed the information from serial evaluations by including the slope of the derived regression line of cervical length over time before dynamic changes in a logistic regression model, alone, and also with the cervical length at the first evaluation. The slope of length over time was not a significant predictor of spontaneous preterm birth before 35 weeks (P = .07). However, after controlling for initial baseline length, the slope became a statistically significant predictor in the regression model (P = .002).

Since previous reports examined the relationship between static cervical length measured beyond 20 weeks’ gestation and spontaneous preterm birth, we performed a secondary analysis of all sonographic evaluations performed at or beyond 21 weeks’ gestation prior to any dynamic changes. If a patient had undergone 2 studies during this gestational period, the former was preferentially selected. In this subgroup of 142 women, the RR of a cervical length less than 25 mm and spontaneous preterm birth before 35 weeks was 3.5 (95% CI, 1.9-6.5). The associated sensitivity and specificity were 46% and 87%, respectively.

Finally, we examined the clinical utility of the shortest observed cervical length not considering dynamic changes on serial scans, using a cutoff of less than 25 mm for the prediction of spontaneous preterm birth before 35 weeks (Table 2). Since cervical lengths tended to shorten over time, more than 4 times as many women (n = 53 vs n = 12) were found to have a cervical length of less than 25 mm during the study.

**Dynamic Changes and Serial Evaluations**

We considered the additional effect of spontaneous or fundal pressure-induced dynamic changes that were observed on serial examinations. We included the shortest observed cervical length after any dynamic changes occurred in a logistic regression model with spontaneous preterm birth before 35 weeks as the dependent variable and found that it was a significantly better predictor than the shortest observed cervical length at any scan prior to dynamic changes. From the regression model, we determined that the odds of spontaneous preterm birth before 35 weeks decreased by 43% for each 5-mm increase in the shortest observed cervical length after dynamic changes.

Considering these dynamic changes, the median rate of shortening remained 1.1 mm per week and 0.9 mm per week after removing the 41 women who had a poorly developed lower uterine segment. We also analyzed cervical length over time after dynamic changes using logistic regression. In this case, the slope was a significant predictor of spontaneous preterm birth before 35 weeks by itself (P < .001) and also after controlling for initial baseline cervical length (P < .001). These analyses confirmed that the inclusion of dynamic changes (ie, shortening) observed on serial evaluations significantly improved the predictive accuracy of endovaginal sonography for a spontaneous preterm birth.

We then examined the summary predictive values of postdynamic change—cervical length measurements at a cutoff of less than 25 mm (n = 60) for the prediction of spontaneous preterm birth before 35 weeks. Table 2 contains the summary predictive values for a cervical length cutoff of less than 25 mm at the baseline scan, the shortest observed cervical length on serial scans before any dynamic changes, and the shortest observed cervical length considering dynamic changes from the serial endovaginal sonographic evaluations.

**Figure 3** depicts the receiver operating characteristic curves of the baseline cervical length at 16 to 18 weeks’ gestation prior to dynamic changes and the shortest observed cervical length observed on serial evaluations after dynamic changes. The latter measurement represented a statistically significant improvement over the former with regard to the use of cervical length as a screening test for the prediction of spontaneous preterm birth before 35 weeks (P = .03).

**COMMENT**

We performed a prospective, blinded observational study to determine if endovaginal sonography of the cervix at 16 weeks’ to 23 weeks’ gestation would predict spontaneous preterm birth with sufficient accuracy to justify mid-trimester intervention trials in high-risk women. As a single measurement, cervical length of less than 25 mm at 16 to 18 weeks’ gestation was a significant predictor of spontaneous preterm birth before 35 weeks, and the inclusion of dynamic shortening and se-

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**Table 2. Summary Predictive Values and Relative Risks (RRs) of Spontaneous Preterm Birth Before 35 Weeks by Cervical Length of Less Than 25 mm at 16 Weeks’ to 18 Weeks’ Gestation and Also Considering the Effect of Serial Sonographic Evaluations and Dynamic Changes Up to 23 Weeks 6 Days’ Gestation**

<table>
<thead>
<tr>
<th>Cervical Length – 25 mm</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Positive Predictive Value, %</th>
<th>Negative Predictive Value, %</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First sonogram before dynamic changes</td>
<td>19</td>
<td>98</td>
<td>75</td>
<td>77</td>
<td>3.3 (2.1-5.0)</td>
</tr>
<tr>
<td>Shortest observed up to 23 weeks 6 days’ gestation before dynamic changes</td>
<td>58</td>
<td>81</td>
<td>53</td>
<td>85</td>
<td>3.4 (2.1-5.5)</td>
</tr>
<tr>
<td>Shortest observed up to 23 weeks 6 days’ gestation after dynamic changes</td>
<td>69</td>
<td>80</td>
<td>55</td>
<td>88</td>
<td>4.5 (2.7-7.6)</td>
</tr>
</tbody>
</table>

*CI indicates confidence interval.*

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of cervical length improved the predictive values. We conclude that the natural history of cervical anatomy during midpregnancy can contribute significant information as to the risk of subsequent spontaneous preterm birth.

We had previously recognized that in approximately 10% of mid-trimester endovaginal sonograms, the cervical anatomy appeared atypical and, in particular, a normal-appearing internal os could not be readily identified. This led to our characterization of a poorly developed lower uterine segment, which in some cases resolved into a measurable cervix. If resolution occurred during the sonogram, this represented a dynamic change. We recognized that, in a few of these transient cases, the cervical length measurement after dynamic change was actually shortened (<25 mm). In other cases, the poorly developed lower uterine segment persisted throughout the entire examination, but resolved before the patient’s next visit. In no cases did this finding persist during all scheduled evaluations. We observed that the incidence of poorly developed lower uterine segments decreased from 16% at the first scan to less than 2% by the fourth evaluation. The finding of a poorly developed lower uterine segment throughout the entire scan appeared to be protective and justified our decision to consider it as a “long” cervix in the analyses. Although primarily a subjective diagnosis, we have summarized diagnostic criteria and believe that it represents a reproducible observation with biological significance.

Our findings challenge previous reports that funneling at the internal cervical os is a useful predictor of preterm birth. We were impressed by the wide range of biological variability associated with funneling, which might limit the reproducibility of this finding. For example, some women did not have a distinctly recognizable shoulder above the functional internal os, depicted in schematic diagrams of funneling, and thus caliper placement was operator dependent. Measurement of funnel width as the distance between shoulders would also have been problematic since some women had only 1 recognizable shoulder. In other cases, asymmetric shoulders occurred, so it was the sonologist’s choice as to which one was used for funnel depth measurement. Based on these observations, we included funneling as a categorical variable in the analyses.

Although women with a funnel had significantly shorter cervical lengths than women with no observed funnel, our analyses confirmed that most, if not all, of the preterm birth risk was related to cervical length. We postulate that some cervixes shorten through the process of funneling, but that the remaining functional length is more important than the precise method of shortening. However, because our sonographic examination windows were necessarily limited (nominally, 20 minutes of real-time observations over 6 weeks), it is plausible that some women with a shortened cervical length had previously experienced funneling that was never observed.

Dynamic change, after controlling for cervical length, was only a marginally significant predictor of preterm birth; however, dynamic cervical length shortening during serial evaluations significantly improved the prediction of preterm birth. Fundal pressure as a provocative maneuver has been evaluated in women at risk for cervical incompetence. We purposely excluded women from our study who had undergone cerclage for a clinical history of cervical incompetence and also recorded unprovoked, spontaneous dynamic shortening. Thus, patient selection likely explains why fundal pressure-induced dynamic changes were not commonly observed. Spontaneous dynamic changes were also uncommon and, as independent findings, did not further improve the predictive value of shortened cervical length for spontaneous preterm birth. We conclude that cervical length is the single most important sonographic finding for preterm birth prediction in high-risk women. Although the precise mechanisms by which the cervix shortens and contributes to spontaneous preterm birth may ultimately be shown to have a differential impact on specific interventions, our results support the concept that for the prediction of spontaneous preterm birth, the means by which the cervix shortens may not be as important as the fact that it does shorten.

Gestational age at examination, obstetric history, concurrent risk factors for preterm birth (eg, multiple gestation), subsequent uncontrolled interventions, the gestational age used to define the preterm outcome, and other aspects of study design likely explain the observed variance among published reports on the significance of cervical length measurement for preterm birth prediction. For these reasons, we defined prematurity as delivery before 35 weeks, which is more clinically relevant than the traditional 37 week end point; included only women with a prior early spontaneous preterm birth; and masked the sonographic results. We chose this study population primarily because it is one of the largest and most
readily identified groups at risk. Although women with multiple gestations also comprise a sizable and homogeneous risk group, the mechanisms by which spontaneous preterm birth occurs in multiple gestations may be different than the pathways that lead to current spontaneous preterm birth in singleton gestations.

To be clinically useful, the measurement of cervical length should be reproducible and associated with reasonable thresholds for intervention. From our quality assurance reviews, we were satisfied that our training and certification resulted in standardized measurements of cervical length among participating sonologists. Since reports of cervical length assessment with endovaginal sonography have become increasingly common in recent years, it is likely that many centers have developed their own training and certification protocols. Nevertheless, from our sonologist certification process, we recognized a learning curve associated with this technique and caution against the use of cervical length assessment by sonologists who have not had appropriate supervised experience.

With regard to intervention thresholds, we recognize that the relationship between cervical length and spontaneous preterm birth functions along a continuum as depicted in a receiver operating characteristic curve (Figure 3). Therefore, no single cervical length cutoff can completely discriminate between eventual term and preterm births. Depending on the risks, effectiveness, and costs of a particular intervention, different thresholds may be appropriate. We believe that a cervical length cutoff of less than 25 mm represents an optimal threshold for inclusion in future mid-trimester intervention trials of cerclage. However, our findings do not support the concept of a “normal” vs “abnormal” cervical length, which is oversimplified. Our findings support the concept that cervical “competence” likely represents a continuum,1,2,24-27 and that the mechanisms that underlie the syndrome of spontaneous preterm birth are multifactorial and incompletely un-

understood.28 Further investigations combining endovaginal sonography and other markers of spontaneous preterm birth may increase our understanding of these mechanisms and permit a more individualized and biologically focused approach to preterm birth prevention. Until properly designed trials of cerclage or other interventions prove a benefit from the finding of a “short” cervix in the mid-trimester,29,30 we recommend that cervical length measurement in women with a prior spontaneous preterm birth remain investigational.

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REFERENCES


Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown. Every good poem, in fact, is a bridge built from the known, familiar side of life over into the unknown. Science too is always making expeditions into the unknown, familiar side of life over into the unknown.

—C. Day-Lewis (1904-1972)