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Is Cervical Elongation Associated with Pelvic Organ Prolapse?

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Abstract

Introduction and Hypothesis—It is commonly believed that pelvic organ prolapse is associated with cervical elongation. However, cervical lengths have not been formally compared between women with prolapse and those with normal support.

Methods—Cervix and uterine corpus lengths were measured on magnetic resonance images in a case-control study of 51 women with prolapse and 46 women with normal support determined by pelvic organ prolapse (POP) quantification (POP-Q) examination. Group matching ensured similar demographics in both groups. Ranges for normal cervical lengths were determined from the values in the control group in order to evaluate for cervical elongation amongst women with prolapse.

Results—The cervix is 36.4% (8.6 mm) longer in women with prolapse than in women with normal pelvic support ($p < 0.001$). Linear regression modeling suggests the feature most highly associated with cervical length is the degree of uterine descent (POP-Q point C). Approximately 40% of women with prolapse have cervical elongation. 57% of cervical elongation in prolapse can be explained by a logistic-regression based model including POP-Q point C, body mass index and menopausal status.

Conclusion—Cervical elongation is found in one-third of women with pelvic organ prolapse, with the extent of elongation increasing with greater degrees of uterine descent.

Keywords

Cervical elongation; Pelvic organ prolapse; Magnetic resonance imaging

INTRODUCTION

The length of the uterine cervix is a widely-studied characteristic in obstetric investigations. However, there is little known about the relationship between cervical length and

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gynecologic conditions. This is especially surprising given that obstetrician-gynecologists regularly use clinical assessments of cervical length for routine decision-making. For example, experienced gynecologic surgeons know that cervical elongation may pose challenges at the time of vaginal or abdominal hysterectomy in seeking to enter the cul-de-sac (from below) or the vagina (from above). Similarly, the length of the cervix may factor into whether uterine-sparing techniques or supracervical hysterectomy are offered rather than total hysterectomy.

There is a commonly-held opinion that pelvic organ prolapse (POP) is associated with cervical elongation [1]. The Pelvic Organ Prolapse Quantification (POP-Q) examination includes measurement of the location of the posterior fornix (point D) with the untested assumption that this measurement is associated with cervical elongation [2]. However, cervical length has not been quantified directly in a study of demographically-matched women with and without pelvic organ prolapse. The goal of this study is to therefore test the hypothesis that the cervix is elongated in women with pelvic organ prolapse, and if so, how frequently and by how much. Variations in apical support as evidenced by differential descent of the uterine cervix and posterior fornix will also be evaluated.

MATERIALS AND METHODS

This is a secondary analysis of an institutional review board-approved case-control study with group matching performed at the University of Michigan to evaluate anterior vaginal wall-predominant pelvic organ prolapse (IRBMED #1999-0395). Subjects were recruited from community advertisements and Urogynecology clinics. All participants had clinical assessment of POP by a urogynecologist using the POP-Q examination [2]. All points were measured in the lithotomy position with the subject's torso at a 45° angle during maximum Valsalva except total vaginal length, which was measured at rest. To qualify as a case, the anterior vaginal wall (point Ba) had to descend at least 1 cm beyond the hymen. This level of prolapse was chosen to ensure that subjects had definite prolapse outside of the normal range established from findings in an asymptomatic population-based group of women [3]. Controls were asymptomatic subjects with all compartments of the vagina at least 1 cm above the hymen. The two groups were recruited to be of similar age, race, gravidity and parity. Exclusion criteria included prior hysterectomy, posterior vaginal wall-predominant prolapse, prior history of surgery for POP or other pelvic floor dysfunction, pregnancy within the prior year, history of pelvic radiation, and history of chronic steroid use or conditions resulting in immunocompromise.

All subjects underwent pelvic magnetic resonance imaging (MRI) as previously described [4]. Briefly, images were obtained at maximum Valsalva in the supine position using a 3T superconducting magnet (Philips Healthcare, Andover, MA, USA). Slice thickness was 6 mm, with a gap of 6 mm.

In order to determine if levator ani (LA) muscle injuries are associated with cervical elongation, LA defects were graded on MR scans as previously described [5]. Briefly, two examiners blinded to subject prolapse status independently evaluated the left and right LA muscles, assigning scores ranging from 0 – 3 to each side. A score of 0 was assigned if no damage was noted, 1 if less than half the muscle was damaged, 2 if more than half, and 3 if the muscle was completely avulsed. The scores from both examiners were compared and the scans were reviewed together by the two reviewers if they differed in their scoring in order to determine a final score. The scores for each side were added together to generate a final LA defect score, ranging from 0 – 6. Major defects were defined as a total score of 4 – 6, or a unilateral grade 3 defect.

For each subject, analysis was performed on the sagittal image with the maximal longitudinal view of the uterine fundus and cervix. Figure 1 shows the measurement scheme. Points were placed at the apex of the mid-fundus, internal cervical os, and external cervical os using ImageJ 1.42q software (National Institutes of Health, Bethesda, MD, USA), and the (x,y) coordinates for each point were determined. The fundus point was selected at the apex of the uterine corpus along the axis of the endometrium. The internal os was identified in the midline of the endometrial canal using a combination of two landmarks: 1) At the junction of the corpus and cervix identified through color and texture changes, e.g., cervical stroma appears darker and more homogenous than the lighter, more granular appearing myometrium, and 2) At the location of maximal narrowing of the corpus. The external os was selected in the midline of the endocervical canal at the external surface of the cervix. Cervical lengths were calculated as the distance between the internal and external os (distance A), and corpus lengths as the distance between the internal os and the uterine fundal apex (distance B). Calculating these lengths separately allowed for more accurate measurements regardless of flexion of the uterine corpus. Total uterine lengths were calculated as the sum of the cervical length and the corpus length (distance A + distance B). All measurements were determined independently by two authors with the average of each used for final analysis. There was high inter-rater reliability in these measurements, with correlation between the two authors averaging 91% (data not shown).

Comparisons were made using independent *t*-tests for continuous variables and chi-squared or Fisher's exact tests for categorical variables. Correlations were assessed using the Pearson correlation coefficient. Linear regression modeling was used to identify characteristics associated with cervical length; logistic regression was used to model factors associated with cervical elongation in women with prolapse. PASW version 18.0 (SPSS, Inc., Chicago, IL, USA) and SAS version 9.1 (SAS Institute, Inc., Cary, NC, USA) were used for statistical analyses.

As there is no published literature on average cervical lengths in women with pelvic organ prolapse, a power calculation could not be calculated *a priori*. However, post-hoc analysis based on our data indicate that with our sample size, we have a statistical power of 99.8% with an alpha error level set at 5% to detect a difference in cervical elongation between the prolapse and normal support groups.

RESULTS

A total of 125 subjects with imaging between January 2006 and November 2009 met the inclusion criteria. Twenty-one subjects were further excluded due to anatomic variations limiting the ability to make accurate measurements, such as distorting uterine fibroids or an oblique orientation of the uterus precluding having the fundus and cervix in the same sagittal image (7/58 women with prolapse and 14/60 women with normal support, $p = 0.15$). The final study population consisted of 97 subjects – 51 cases with clinically-identified prolapse at least 1 cm beyond the hymen and 46 controls with normal pelvic support. There were no significant demographic differences between the excluded subjects and the included subjects (variables tested included age, height, BMI, gravidity, parity, menopausal status, usage of estrogen replacement or sexual activity, data not shown). Demographic and prolapse characteristics of each group are presented in Table 1. As expected from the study design, women with prolapse had higher rates of more advanced POP-Q stages, and demographic characteristics were similar.

Prolapse is associated with elongation of both the cervix and uterus (Figure 2). For each analysis we present data concerning 1) cervical length (in mm) and 2) the ratio of cervical length to corpus length (in order to control for the overall size of the pelvic organs), as has

been previously described [6]. The cervix measures 36.4% (8.6 mm) longer in women with prolapse than those with normal support ($p < 0.001$), whereas the corpus length is 11.3% (4.9 mm) longer in women with prolapse ($p = 0.012$). The total uterine length is 20.1% (13.5 mm) longer in women with prolapse ($p < 0.001$). The ratio of the cervix:corpus length is 21.8% greater in women with prolapse than in those with normal support ($p = 0.003$).

We next examined correlations between the apical components of the POP-Q examination (points C and D) and MRI-based cervical length measurements. We found significant correlation between the length of the cervix (in mm) and all apical POP-Q measures (the location of points C and D as well as the distance between points C and D) when examining the entire study population (Pearson correlation coefficients (ρ) ranged from 0.41 to 0.59, p values all < 0.0001). These relationships are similar, both in magnitude and significance, when analyzing only women with prolapse (data not shown). However, in women with normal support, the only significant correlation is between the cervical length measured as the cervix:corpus length ratio and the location of POP-Q point D ($\rho = 0.348$, $p = 0.02$). There is a trend towards correlation between the length of the cervix (in mm) and POP-Q point C in the control subjects ($\rho = 0.269$, $p = 0.07$), but it did not reach statistical significance.

Linear regressions were performed to identify demographic and/or prolapse characteristics associated with variation in cervical length. The independent variables tested included age, menopausal status, locations of POP-Q points C and D, the distance between points C and D, the most dependent POP-Q point, body mass index (BMI), parity, and case/control categorization. In one-variable models, the degree of uterine descent as assessed by POP-Q point C is the factor most strongly correlated with increased cervical length, regardless of the definition of cervical length used. For example, 34% of the variability in the cervical length can be explained by the descent of point C (R -squared = 0.34). Similarly, 31% of the variability in the ratio of cervix:corpus lengths is explained by the location of point C (R -squared = 0.31). By contrast, there is no improvement in explaining the variability of these length measures by using the distance between points C and D; the R -squared values are 0.29 and 0.24, respectively, for absolute cervical length and the cervix:corpus ratio.

The linear regression models were then expanded to include multiple variables in order to identify characteristics useful for predicting cervical length (Table 2). In all analyses, the most important factor was the location of POP-Q point C. When examining the absolute length of the cervix, the final model included menopausal status and the location of POP-Q point C, with an adjusted R -squared of 0.51. The model predicting the ratio of the cervical length to the uterine corpus length contains only the distance of POP-Q point C, with an adjusted R -squared of 0.30.

To determine the percentage of women with prolapse that have cervical elongation, we determined the range of normal for cervix, corpus and total uterine lengths using measurements from the cohort with normal support. We defined the upper limit of normal for each length via a standard 95% confidence interval (the sum of the mean plus 1.96 standard deviations), as follows: cervical length 33.8 mm, corpus length 63 mm and total uterine length 94 mm. The upper limit of normal for the ratio of the cervix:corpus lengths is 0.79. Significantly more women with prolapse than normal support had cervical elongation based on each of these definitions. One subject in the control group (2.2%) had an absolute cervical length longer than 33.8 mm as compared to 20 (39.2%) of the women with prolapse ($p < 0.001$). Similarly, 12 women with prolapse (23.5%) had cervical elongation as compared to 2 (4.3%) control subjects ($p = 0.007$) based on the ratio of the cervical length to the corpus length. However, as our definitions of normal cervical lengths were derived from

our control group, it is appropriate to study cervical elongation only in our cohort of women with prolapse.

We compared women with cervical elongation to those with cervical lengths within the normal range in order to look for characteristics associated with cervical elongation among women with prolapse. We used each definition of cervical elongation as described above. Demographic and prolapse characteristics are presented in Table 3.

Logistic regression was used to identify which characteristics best independently predict cervical elongation in women with prolapse. Again, each definition of cervical elongation was used in these analyses, and the same independent variables were used as in the linear regressions described above. In the prediction of cervical elongation based on the absolute cervical length being greater than 33.8 mm, the final model includes BMI, POP-Q point C and menopausal status. 57% of cervical elongation can be explained by this model (max-rescaled R-squared = 0.57), and this model has excellent sensitivity and specificity (the area under the curve (AUC) of the receiver operating characteristic (ROC) curve = 0.90) (Table 4). Using the definition of cervical elongation as the ratio of cervical length:corpus length > 0.79, the model includes BMI, POP-Q point C and parity. This model explains 56% of cervical elongation (max-rescaled R-squared= 0.56) with excellent sensitivity and specificity (ROC AUC = 0.90) (Table 4).

DISCUSSION

The results of this study suggest that approximately 40% of women with anterior-predominant pelvic organ prolapse have cervical elongation as compared to women with normal pelvic support. Both the cervix and the uterine corpus are longer in women with prolapse than in those with normal support, but the cervix elongates proportionately more. To our knowledge, this is the first study to evaluate cervical elongation by pelvic imaging, rather than through clinical examination [7, 8]. This is also the first study that establishes criteria for defining prolapse-associated cervical elongation based on measures made in age-, race- and parity-matched women with prolapse and those with normal pelvic support.

It is currently unknown if the differences in cervical and corpus lengths identified in this study are clinically meaningful, as until now, there has been no reliable means to quantifiably assess for cervical elongation. This study provides the normal ranges of uterine measurements in both women with prolapse and women with normal support, which may be useful for future studies. Such studies could be performed with a variety of imaging techniques, including MRI or ultrasound.

This study quantifies the relationship between the degree of prolapse present and the extent of cervical elongation. When looking at all subjects in the study, stratification as prolapse or normal adds little to predicting the length of the cervix. However, we must acknowledge that the cases included in this study were comprised only of women with anterior vaginal wall-predominant prolapse. We selected this group as it is the population for which we had sufficient numbers of MRIs available to perform the analysis, but it is certainly possible that inclusion women with apical- and/or posterior vaginal wall-predominant prolapse could alter our findings. In addition, as we defined cervical elongation using normative data from our control subjects, we can only reasonably assess cervical elongation in the subjects with prolapse. Our data suggest that approximately 30% of cervical elongation is explained by cervical descent.

There are several clinical scenarios in which cervical elongation plays an important role. One involves the decision between hysterectomy and uterine preservation during pelvic organ prolapse repair. Although hysterectomy has classically played a role in pelvic floor

reconstructive surgeries, uterine-sparing procedures are becoming more common [9, 10]. However, preoperative cervical elongation is a relative contraindication for uterine preservation and necessitates additional cervical amputation for improved outcomes [9]. In addition, postoperative cervical elongation has been reported after uterine-sparing surgeries [11].

Cervical elongation may also affect one's decision about peritoneal entry sites during a vaginal hysterectomy. If a surgeon is aware of cervical elongation at the beginning of a vaginal hysterectomy, the location of the initial circumferential incision and appropriate extraperitoneal dissection may be better anticipated [12]. Pelvic imaging is not necessary prior to proceeding to the operating room, but knowledge about demographic and prolapse characteristics that may help predict cervical elongation would allow for better surgical preparation. The models from our study highlight key anatomic and demographic characteristics that allow for more accurate preoperative predictions of cervical elongation. Our data suggest, for example, that younger, premenopausal women with uterine descent are more likely to have a longer cervix than older women with better apical support.

The standard POP-Q examination includes measurement of point D, the posterior fornix, to include identification of the presumed insertion site for the uterosacral ligaments [2]. This was based on the untested assumption that a large distance between point C (the leading edge of the cervix) and point D indicate cervical elongation, whereas descent of point D suggests failure of uterine apical support [2, 8, 13]. This has led to a common clinical practice of using the C-to-D distance as a proxy measure for cervical length. We find that the location of point C alone, and not the distance between points C and D, is the strongest predictor of cervical length and elongation. We similarly find the strongest correlations between cervical length (using both definitions) and POP-Q measures using point C alone. It should be acknowledged, though, that the technique used to measure the location of point D, e.g., palpation alone or with the use of a cotton-tipped swab, may artificially deform the vaginal topography and affect the measurement. We would nonetheless like to call attention to the fact that point D does capture an element of upper posterior vaginal support, so we are not suggesting that it be abandoned; rather that the distance between points C and D be re-evaluated as a predictor of cervical length and/or elongation.

It is interesting that in both this study and a recent paper from Ibeanu, et al., the average location of POP-Q point D remains reasonably well suspended for all subjects, including those with cervical elongation [8]. With our definition of cervical elongation based on absolute cervical length, we find no significant difference in the location of point D in women with prolapse between those with and without cervical elongation (Table 3). For the definition based on the ratio of the cervix:corpus lengths, although there is a statistically-significant difference in the location of point D between the two groups, the difference likely has little clinical relevance. This differential descent of the uterine cervix and the posterior fornix highlights the fact that apical support that is provided by the cardinal and uterosacral ligaments is not uniformly distributed across the entire cervix and vaginal apex. This has similarly been shown through pelvic dissections, histopathologic examinations and imaging studies [14–17].

It is not understood why the cervix may elongate and descend while the upper vagina and corpus remain well-suspended. Two possible mechanisms for this phenomenon include: 1) women with prolapse have inherently longer cervixes, or 2) descent of the developing prolapse causes elongation of the cervix through downward traction. We cannot discriminate between these two theories with our study design, but we favor the second hypothesis, and further investigation is necessary to resolve this issue. Similarly, this imaging-based study does not allow us to comment on possible roles played by differences in tissue biochemistry,

genetics or connective tissue, all of which have been shown to be associated with pelvic floor disorders [18, 19].

Ibeanu and colleagues defined cervical elongation clinically as a C-to-D distance ≥ 8 cm [8]. There are several interesting outcome differences between their analysis and our current study. We find that women with cervical elongation, as defined by the ratio of the cervix:corpus lengths, tend to have lower parity than women with cervical lengths within normal limits, whereas Ibeanu and colleagues found the opposite. They also identified no significant age differences between women with cervical elongation and their control groups, whereas we found that women with longer cervixes (as measured in millimeters), were significantly younger than the women with cervical lengths within the normal range. We suspect that the discrepancies between our findings and those in their study relate to differences in study design. For example, cervical elongation in our study was determined from pelvic imaging, whereas clinical examination was used in their study. Our control group consisted of women with normal pelvic support volunteering for a research study, as compared to the control group in their study composed of women with normal pelvic support but with symptomatic uterine fibroids seeking surgical management. Finally, there are significant differences in the racial compositions of the two studies. These all may contribute to the differences in our findings and are important areas for future consideration.

Previous studies have identified various demographic factors associated with the size of the uterine corpus and cervix, including age/menopausal status and parity [6, 20–22]. Based on the data from these papers, we would predict, for example, that multiparous, premenopausal women are more likely to have larger uteri and cervixes. However, there are few published data about the relative sizes of the cervix and corpus. The relationships between these measures and pelvic organ prolapse are similarly scarce. We therefore explored the associations between multiple demographic characteristics and cervical elongation measures.

Women with cervical elongation, as defined by an absolute cervical length greater than 33.8 mm, are more likely to be young and premenopausal than women with normal cervical lengths. This finding is consistent with previous studies demonstrating decreasing cervical and uterine corpus lengths as women progress past the menopausal transition [6, 20].

We only find a significant difference in parity when using the definition of cervical elongation based on the ratio of cervix:corpus lengths, whereas Merz and colleagues found no significant difference in this ratio when analyzing women of increasing parity [6]. By contrast, they did find that both the uterine corpus and cervix increased in length when comparing women of higher parity to nulliparas or primiparas. The comparisons based on parity in the Merz study were performed only in premenopausal women, so it is likely that the discrepancy between their results and those from our study are likely a consequence of different subject demographics.

Although the average body mass index is similar in women with cervical elongation and those with normal cervical lengths, we find that prediction of cervical elongation is significantly improved through inclusion of BMI. As this is a case-control study, we cannot determine causality or the temporal relationships between the demographic characteristics included in our study and cervical elongation. However, we hypothesize that higher BMI is associated with a lower likelihood of cervical elongation due to altered hormonal and/or metabolic milieu, differential effects of increased intraabdominal pressure on the pelvic floor and support structures, or a combination thereof. Interestingly, Londero and colleagues did not find a significant association between cervical length and BMI in a multivariable

model, but their study was limited by inclusion of only premenopausal women, and most had BMI within the normal range [22].

Finally, we found no significant differences in total levator ani defect scores or the percentage of women with major LA defects when comparing women with prolapse and cervical elongation to those with prolapse but normal length cervixes. We do note, however, a trend towards higher total LA defect scores and proportion of subjects with major defects in the cervical elongation groups, irrespective of definition of cervical elongation used. It is possible that we lacked sufficient power to detect a significant difference in levator injuries between these groups. However, although levator ani trauma is strongly associated with pelvic organ prolapse [23, 24], our findings may reflect the fact that all of the subjects in the cervical elongation subanalysis have prolapse, and cervical elongation may therefore be driven by a different underlying mechanism.

Cervical elongation is a common, though not universal, finding in women with anterior-predominant pelvic organ prolapse. The pathophysiologic mechanism(s) underlying the development of cervical elongation are currently not well understood, and therefore require continued evaluation. Differential descent of the uterine cervix and the posterior fornix emphasize anatomic and functional differences in apical support that are important targets for future studies necessary for understanding not only why prolapse develops, but how to prevent its occurrence and to guide improvements in surgical approaches for apical reconstruction.

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Figure 1.

Cervical length (A) was calculated as the distance between the external cervical os (point 1) and the internal cervical os (point 2). Uterine corpus length (B) was calculated as the distance between the internal os (point 2) and the uterine fundus (point 3).

Figure 2.

Cervical, uterine corpus and total uterine lengths in women with prolapse and normal support. Data are presented as mean $\pm$ standard error of the mean. All comparisons between women with prolapse and normal support are statistically significant.

Table 1

Demographic and Prolapse Characteristics – Subjects with Normal Support Compared to those with Pelvic Organ Prolapse

Characteristic	Normal Support (N = 46)	Prolapse (N = 51)	p value
Demographics			
Age (years)	54.8 ± 10.6	54.9 ± 10.7	0.98
BMI (kg/m ²)	27.0 ± 6.3	27.4 ± 5.9	0.75
Height (inches)	64.4 ± 2.5	64.8 ± 2.8	0.45
Gravidity	3.2 ± 1.7	3.4 ± 1.6	0.57
Parity	2.6 ± 1.3	2.7 ± 1.3	0.72
Prior cesarean delivery (%)	11.1 (5/45)	5.9 (3/51)	0.47
Race (% Caucasian)	87.0% (40/46)	86.3% (44/51)	0.92
Postmenopausal (%)	60.9 (28/46)	62.7 (32/51)	0.85
Using ERT (%)	2.2 (1/45)	8.2 (4/49)	0.36
Sexually Active (%)	57.8 (26/45)	50 (25/50)	0.45
LA Defect Score	1.2 ± 1.5	2.2 ± 2.3	0.016
Major LA Defects	15.2% (7/46)	34.7% (17/49)	0.04
POP-Q Points and Stages			
Ba (cm)	-1.8 ± 0.8	2.8 ± 1.8	<0.001
C (cm)	-6.6 ± 1.5	-1.0 ± 4.2	<0.001
D (cm)	-8.7 ± 1.6	-5.6 ± 2.7	<0.001
Distance between Points C and D (cm)	2.0 ± 1.1	4.6 ± 2.9	<0.001
Bp (cm)	-1.8 ± 0.6	-1.1 ± 1.5	0.004
Most Dependent Point (cm)	-1.5 ± 0.7	3.0 ± 2.0	<0.001
Genital Hiatus (cm)	3.2 ± 1.0	5.8 ± 1.5	0.001
Perineal Body (cm)	3.6 ± 1.2	2.9 ± 0.9	0.001
Total Vaginal Length (cm)	10.4 ± 1.2	9.9 ± 1.1	0.02
Stage 0	4.3 (2/46)	0	0.22
Stage 1	45.7 (21/46)	0	<0.001
Stage 2	50 (23/46)	35.3 (18/51)	0.16
Stage 3	0	62.7 (32/51)	<0.001
Stage 4	0	2.0 (1/51)	1.00

Data are presented as follows: Mean ± Standard Deviation or Percentage (Total number subjects per group with the characteristic/Total number in group for which data are available).

p values represent comparisons between women with prolapse and those with normal support.

BMI = Body mass index; ERT = Estrogen replacement therapy.

Prior Cesarean Delivery: Defined as the percentage of women having had at least one Cesarean delivery.

Table 2

Linear Regression Models for Cervical Lengths

Independent Variable	Parameter Estimate	Standard Error	p value
<i>Prediction of Cervical Length (mm)</i>			
Intercept	39.2	1.4	< 0.0001
POP-Q Point C	1.5	0.2	< 0.0001
Postmenopausal Status	-8.8	1.5	< 0.0001
<i>Prediction of the Ratio of Cervical:Corpus Lengths</i>			
Intercept	0.7	0.02	< 0.0001
POP-Q Point C	0.03	0.004	< 0.0001

Multivariable linear regressions were performed to identify factors that significantly associate with cervical length, using both definitions of cervical length as described in the text. The sample size was 97 subjects for each model. For the model of absolute cervical length in mm, the overall F-statistic is 51.3 with a p value of < 0.0001, and the R-squared value for the model is 0.52. For the regression based on the cervix:corpus ratio, the overall F-statistic is 41.9 with a p value of < 0.0001, and the R-squared value is 0.31.

POP-Q = Pelvic Organ Prolapse – Quantification

Postmenopausal Status: 1 if postmenopausal, 0 if premenopausal

Table 3

Characteristics of Women with Prolapse with and without Cervical Elongation

Characteristic	Cervical Length > 33.8 mm			Cervix:Corpus Ratio > 0.79		
	Normal Length (N = 31)	Cervical Elongation (N = 20)	p value	Normal Length (N = 39)	Cervical Elongation (N = 12)	p value
<i>Demographics</i>						
Age (years)	57.7 ± 10.1	50.5 ± 10.2	0.02	55.2 ± 10.9	54.0 ± 10.4	0.74
BMI (kg/m ²)	28.1 ± 6.4	26.3 ± 5.1	0.25	27.2 ± 6.2	26.3 ± 4.8	0.41
Height (inches)	64.6 ± 2.1	65.2 ± 3.7	0.49	65.0 ± 3.1	64.3 ± 1.5	0.31
Gravidity	3.5 ± 1.5	3.4 ± 1.8	0.78	3.7 ± 1.7	2.7 ± 0.8	0.06
Parity	2.7 ± 1.2	2.7 ± 1.6	0.92	2.9 ± 1.4	2.2 ± 0.8	0.03
Prior Cesarean Delivery (%)	6.5 (2)	5 (1)	1.00	7.7 (3)	0 (0)	1.00
Race (% White)	90.3 (28)	80 (16)	0.41	89.7 (35)	75 (9)	0.33
Postmenopausal (%)	77.4 (24)	40 (8)	0.009	64.1 (25)	58.3 (7)	0.74
Using ERT (%)	10.3 (3/29)	5 (1/20)	0.64	10.8 (4/37)	0	0.56
Sexually Active (%)	46.7 (14)	55 (11)	0.56	55.3 (21/38)	33.3 (4)	0.19
LA Defect Score	2.1 ± 2.1	2.4 ± 2.5	0.65	2.0 ± 2.2	2.9 ± 2.4	0.29
Major LA Defects	26.7% (8/30)	47.4% (9/19)	0.22	28.9% (11/38)	54.5% (6/11)	0.16
<i>POP-Q Points and Stages</i>						
Ba (cm)	2.7 ± 1.6	2.9 ± 2.1	0.74	2.4 ± 1.6	3.9 ± 2.1	0.01
C (cm)	-2.1 ± 3.5	0.7 ± 4.7	0.02	-2.2 ± 3.6	2.8 ± 4.0	0.001
D (cm)	-5.9 ± 2.7	-5.2 ± 2.8	0.34	-6.0 ± 2.8	-4.4 ± 2.2	0.04
Distance Between Points C and D (cm)	3.8 ± 2.4	5.9 ± 3.1	0.01	3.8 ± 2.4	7.2 ± 3.0	<0.001
Bp (cm)	-1.3 ± 1.5	-0.8 ± 1.5	0.19	-1.2 ± 1.4	-0.8 ± 1.8	0.55
Most Dependent Point (cm)	2.8 ± 1.7	3.3 ± 2.3	0.34	2.5 ± 1.7	4.6 ± 2.0	0.005
Genital Hiatus (cm)	5.5 ± 1.4	6.4 ± 1.6	0.05	5.6 ± 1.3	6.8 ± 1.6	0.03
Perineal Body (cm)	2.9 ± 0.7	2.9 ± 1.2	0.96	3.1 ± 0.8	2.4 ± 1.0	0.06
Total Vaginal Length (cm)	9.8 ± 1.1	10.0 ± 1.2	0.62	9.9 ± 1.2	9.6 ± 0.9	0.35
Stage 2	35.5 (11)	35 (7)	0.97	43.6 (17)	8.3 (1)	0.04
Stage 3	64.5 (20)	60 (12)	0.75	56.4 (22)	83.3 (10)	0.17
Stage 4	0	5 (1)	0.39	0	8.3 (1)	0.24

Data are presented as follows: Mean $\pm$ Standard Deviation or Percentage (Total number subjects per group). When data are missing from binomial characteristics, the data are presented as Percentage (Total number subjects per group with the characteristic/Total number in group for which data are available).
 p values represent comparisons between women with prolapse and those with normal support.
 BMI = Body mass index; ERT = Estrogen replacement therapy; LA = Levator ani; POP-Q = Pelvic Organ Prolapse – Quantification.
 Prior Cesarean Delivery: Defined as the percentage of women having had at least one Cesarean delivery.

Table 4

Logistic Regression Models for the two Definitions of Cervical Elongation

Independent Variable	Odds Ratio	95% CI	Regression Coefficient	Standard Error	p value
<i>Cervical Elongation Defined as Cervical Length > 33.8 mm</i>					
Intercept	----	----	7.17	2.65	0.007
BMI	0.83	0.70 – 0.98	–0.19	0.08	0.03
POP-Q Point C	1.64	1.22 – 2.22	0.50	0.15	0.001
Postmenopausal Status	0.02	0.002 – 0.21	–3.99	1.23	0.001
<i>Cervical Elongation Defined as the Ratio of Cervix:Corpus Lengths > 0.79</i>					
Intercept	----	----	7.63	3.62	0.04
BMI	0.81	0.67 – 0.99	–0.21	0.10	0.03
POP-Q Point C	1.67	1.21 – 2.30	0.51	0.16	0.002
Parity	0.26	0.07 – 0.89	–1.36	0.64	0.03

Multivariable logistic regressions were performed to identify factors that significantly associate with cervical elongation using both definition described in the text. The sample size was 51 subjects (only women with prolapse were included). For the model based on absolute cervical length, the maximum-rescaled R-squared value is 0.57, and the receiver operating characteristic area under the curve (ROC AUC) is 0.90. In the model using the ratio-based definition of cervical elongation, the maximum-rescaled R-squared value is 0.56, and the ROC AUC is 0.90.

BMI = Body Mass Index; POP-Q = Pelvic Organ Prolapse – Quantification

Postmenopausal Status: 1 if postmenopausal, 0 if premenopausal