Computerized planimetry versus clinical assessment for the measurement of cervical ectopia

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OBJECTIVE: As part of a study to assess the role of cervical ectopia in the acquisition of cervical infections, we determined the reliability of cervical ectopia measurements made by computer planimetry and by clinical (visual) assessment.

STUDY DESIGN: We conducted pelvic examinations of 1004 women seeking contraceptive services at two health centers in Baltimore. After application of acetic acid, clinicians estimated the relative area of ectopia by visual inspection and took cervical photographs. Two independent raters measured the absolute and relative areas of ectopia from the digitized images by means of an analytic software program. Agreement levels between raters, between multiple readings by the same rater, and between the two measurement methods were quantified by means of the intraclass correlation coefficient and weighted k.

RESULTS: Intrarater agreement was excellent for computer planimetry measurements of the absolute (intraclass correlation coefficient, 0.97) and relative (intraclass correlation coefficient, 0.89) areas of ectopia. Interrater agreement was also high for computer planimetry measurements of the absolute (intraclass correlation coefficient, 0.83) and relative (intraclass correlation coefficient, 0.85) areas of ectopia. Agreement levels were moderate between clinician assessment and computer planimetry measurements of the relative area of ectopia (k = 0.48), but agreement was better when clinical assessment was limited to observations by a single, experienced clinician.

CONCLUSION: Measurement of cervical ectopia by computer planimetry was highly reliable and appears appropriate for assessment of the role of ectopia in the acquisition of cervical infections. Clinical assessment of cervical ectopia may be used when computer planimetry is not available. (Am J Obstet Gynecol 2001;184:1170-6.)

Key words: Cervix, ectopia, measurement, reliability, sexually transmitted infections

Cervical ectopia, the presence of columnar epithelium on the ectocervix, consists of a single layer of glandular cells that are highly vascular relative to the squamous epithelium lining the vagina and the ectocervix. Cervical ectopia is common among adolescent girls, pregnant women, and women who use combined oral contraceptives. Cervical ectopia appears to be important in the transmission of some sexually transmitted infections. Many studies have reported an association between the prevalence of cervical ectopia and prevalent or incident chlamydial infections. This relationship is biologically plausible. Columnar epithelium consists of a single cell layer, is vascular and mucus secreting, and is the preferred tissue for Chlamydia trachomatis infection. Studies have also reported an association between cervical ectopia and prevalent" and incident" HIV infections and increased HIV genital shedding in some but not all studies. Associations between cervical ectopia and human papillomavirus infection, cervical intraepithelial neoplasia, cytomegalovirus infection, and cervicitis have also been reported. Cervical ectopia does not appear to be associated with gonococcal infection.

Because of the potential role of cervical ectopia in the acquisition of sexually transmitted infections, a number of recent studies have measured cervical ectopia. Most commonly cervical ectopia has been measured clinically by visual assessment after application of 3% to 5% acetic acid to the ectocervix. Generally, clinicians have recorded the presence or absence of ectopia according to the ability to visualize any columnar epithelium on the ectocervix. Other clinical assessments have used ordinal measures, for example, categorizing whether ectopia was either absent or present on approximately one fourth, one half, three quarters, or the entirety of the ec-
Another approach has been to estimate the greatest radius of ectopia relative to the radius of the entire ectocervix. Clinicians have also estimated the absolute area of cervical ectopia, for example, noting whether cervical ectopia was >2 cm in diameter. Cervical ectopia has also been measured from photographs taken with either a colposcope or a 35-mm camera. Either a grid or a pie chart with slices has been superimposed over the photographs to estimate the proportion of the cervix with ectopia. Another approach has been to project color slides onto a screen and have raters visually estimate the proportion of ectopia from the projected images. More recent studies have used computer planimetry to measure cervical ectopia. In these studies acetic acid was applied to the cervix and cervical images were taken with a specially designed 35-mm camera (Cerviscope; NTL processing Inc, Fenton, Mo) with a fixed-magnification macro lens and a built-in ring flash. A rater then used digitized images to outline the area of ectopia on the computer screen, and the outlined area was measured with an analysis program. In a similar manner the areas of the ectocervix, the cervical os, and immature squamous metaplasia were also measured. In addition to measuring the proportion of the ectocervix with ectopia, one study also estimated the absolute area of ectopia by photographing the cervix with a standard focal length and preadjusted settings and using trigonometry to calculate the area of ectopia. The ability to measure cervical ectopia reliably is important to our understanding of the role of cervical ectopia in the acquisition of sexually transmitted infections. Moreover, if further research confirms the role of cervical ectopia in sexually transmitted infection acquisition, it will be important to determine whether clinicians can reliably assess cervical ectopia during routine clinical procedures (by visual inspection). Only one study has conducted an in-depth evaluation of the reliability of cervical ectopia measurements. In that study raters measured cervical ectopia by three methods (visual assessment with and without acetic acid and computer planimetry with acetic acid) at 2 time points. Agreement levels were high for computer planimetry and were good for visual inspection with and without acetic acid. The authors concluded that cervical ectopia measurements by computer planimetry provided the most reliable estimates but that visual assessment with acetic acid can be used if computer planimetry is not available. This report evaluates our attempts to improve on previous measures of cervical ectopia, particularly in measuring the absolute area of ectopia. We report on the reliability of cervical ectopia measurements made with computer planimetry and with clinical (visual) assessment techniques, including measures of the absolute and relative areas of cervical ectopia. 

Material and methods

This research study was approved by the Protection of Human Subjects Committee of Family Health International, Research Triangle Park, NC, and by the Institutional Review Board on Research Involving Human Subjects of the School of Public Health at the University of North Carolina, Chapel Hill. All women provided written informed consent before study participation.

Study population and procedures. As part of a prospective study to evaluate the role of hormonal contraception in the development of cervical ectopia and cervical infections, we enrolled 1004 women seeking gynecologic care at 2 Planned Parenthood of Maryland health centers. Study participants were 15 to 44 years of age and either were initiating the use of combined oral contraceptives or depot medroxyprogesterone acetate or were not using a hormonal contraceptive method (control group). Women could not have used a hormonal contraceptive for one complete menstrual cycle before enrollment and could not be pregnant.

At the baseline visit we interviewed women to collect sociodemographic, sexual behavior, and reproductive (including contraceptive) history data. A nurse practitioner or physician assistant conducted a standardized pelvic examination that noted the condition of the external genitalia, the vagina, and the cervix. After application of 4% acetic acid, we placed a small adherent vinyl dot of known diameter (0.476 cm) onto the ectocervix (in the plane of the cervical os) but outside the area of ectopia (if possible). Clinicians then used a 35-mm “dental-eye” camera (Yashica; B&O International, Inc, San Diego, Calif) with a ring flash at a standardized magnification setting and focal length to take 3 images of the cervix, refocusing the camera before taking each new picture. Then on the basis of unmagnified visual assessment the clinician was asked to outline the area of cervical ectopia on a circular diagram of the cervix and to estimate the proportion of the cervix with ectopia (none, <25%, 25% to 50%, >50% to <75%, or >75%).

Measurement of cervical ectopia by computer planimetry. One trained rater (Irina Yacobson) measured cervical ectopia with computer planimetry for all participants. We then drew a random sample of 120 images from the baseline ectopia images, and the same rater and a second trained rater (Charles Morrison) re-measured the images. Sprint Scan (Polaroid Corporation, Cambridge, Mass) software was used to scan the slides. All images were saved as digitized files, and ectopia measurements were made with SigmaScan (SPSS Inc, Chicago, Ill) imaging analysis software. Measurements were calibrated against the vinyl dot (0.476 cm) that was placed on the cervical surface. Calibration was done by tracing the diameter of the dot and finding the equivalent of 0.476 cm in pixels. The diameter of the cervix was measured by drawing a line through the cervical os, when possible, from the 10...
Fig 1. Image of cervix illustrating measurement of area of cervical ectopia (A), diameter of ectocervix (B), and diameter of vinyl dot used for calibration (C).

o'clock position to the 4 o'clock position or from the 2 o'clock position to the 8 o'clock position (Fig 1). Cervical ectopia was measured by tracing the line around the area of columnar epithelium and calculating the absolute area of cervical ectopia within this perimeter. The area of columnar epithelium was also measured in cases in which the cervical os was open and the only visible columnar epithelium was inside the os. In such cases a comment was made in the database to indicate that the identified columnar epithelium was located exclusively inside the cervical os.

Statistical analysis. Of the 1004 women enrolled in the study, 987 (98.3%) had evaluable cervical photographs. We report descriptive statistics for the 929 with both computer planimetry and clinician assessments (made by clinicians with a minimum of 20 ectopia readings) and for a random sample of 120 women drawn from all baseline images available at the time of analysis.

We used the intraclass correlation coefficient to measure the consistency and reliability. Separate analyses were conducted to calculate the intraclass correlation coefficients as estimates of the interrater and intrarater reliabilities. For interrater reliability a 2-way analysis of variance model with fixed rater effect was used, under the assumption that both raters (Irina Yacobson and Charles Morrison) were the only raters of interest. For intrarater reliability a 1-way analysis of variance model was used in which the total variance was split into within-image and between-image variability. Calculation of intraclass correlation coefficients, calculation of 95% confidence intervals, and hypothesis testing were based on the assumption that computer planimetry measurements were normally distributed. When the normality assumption was not met, we also estimated interrater and intrarater agreement with the weighted $k$ statistic.

Because the clinical assessment technique assessed the proportion of the cervix with ectopia categorically rather than as a continuous measure, we calculated the level of agreement between the computer planimetry and clinician assessment techniques with the weighted $k$ statistic.
Table I. Quartiles of absolute area of ectopia and proportion of cervix with ectopia measured by computer planimetry method by raters Irina Yacobson (initial and repeat) and Charles Morrison (n = 120)

<table>
<thead>
<tr>
<th>Quartiles</th>
<th>Absolute area of cervix with ectopia (cm²)</th>
<th>Proportion of cervix with ectopia</th>
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<tbody>
<tr>
<td>100% (maximum)</td>
<td>7.23</td>
<td>5.79</td>
</tr>
<tr>
<td>75% (3rd quartile)</td>
<td>0.47</td>
<td>0.40</td>
</tr>
<tr>
<td>50% (median)</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>25% (1st quartile)</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>0% (minimum)</td>
<td>0</td>
<td>0</td>
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Table II. Interrater and intrarater measures of agreement and 95% confidence intervals for absolute area of ectopia and proportion of cervix with ectopia measured by computer planimetry method (n = 120)

<table>
<thead>
<tr>
<th></th>
<th>Absolute area of cervix with ectopia</th>
<th>Proportion of cervix with ectopia</th>
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<tbody>
<tr>
<td></td>
<td>Intrarater (rater I.Y. vs repeat)</td>
<td></td>
</tr>
<tr>
<td>Estimated intraclass correlation coefficient (ICC)</td>
<td>Value</td>
<td>0.97</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>Value</td>
<td>0.95-0.98</td>
</tr>
<tr>
<td></td>
<td>Weighted κ (κ)</td>
<td></td>
</tr>
<tr>
<td>Estimated intraclass correlation coefficient (ICC)</td>
<td>Value</td>
<td>0.85</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>Value</td>
<td>0.76-0.88</td>
</tr>
<tr>
<td></td>
<td>Weighted κ (κ)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>0.88*</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>Value</td>
<td>0.77-0.89</td>
</tr>
</tbody>
</table>

*Five categories were used for the absolute area as follows: <0.075 cm², 0.075-0.15 cm², 0.15-0.3 cm², 0.3-0.7 cm², and ≥0.7 cm².
†Five categories were used for the proportion of the cervix covered by ectopia as follows: <5%, 5%-25%, 25%-50%, 50%-75%, and ≥75%.

We used SAS, version 6.12 (SAS Institute, Inc, Cary, NC), for all analyses. The type I error rate was set at .05, 2-tailed, unadjusted for multiple comparison.

**Results**

We enrolled women who primarily were single (76%), had graduated from high school (79%), and were nulliparous (75%). About two thirds of the women (65%) were <25 years old, including 14% aged 15 to 17 years. About 54% of the participants were white, and 41% were African American. About half of the participants (49%) had 20 lifetime sexual partners, and 75% reported the use of male condoms at some time in the previous 3 months. Almost two thirds (65%) had previously used combined oral contraceptives, and 14% had previously used depot medroxyprogesterone acetate. At baseline, 19% of women had abnormal vaginal discharge, 26% had a friable cervix, and 5.1% and 0.9% had chlamydial and gonococcal infections, respectively.

The median absolute areas of the cervix with ectopia as measured by computer planimetry varied from 0.17 to 0.19 cm², with individual areas ranging from 0 to 7.45 cm² for rater Irina Yacobson (initial), rater Charles Morrison, and rater Irina Yacobson (repeat; Table I). Most women had small areas of ectopia; however, almost a quarter of participants had areas of ectopia ≥0.5 cm². The median proportion of the cervix with ectopia ranged from 0% to 8% for the 3 sets of measurements. Again, individual measurements varied across a wide range, with each rater having measurements ranging from 0% to 100%.

Levels of intrarater and interrater agreement were extremely high. Intrarater agreement was excellent for the absolute area of the cervix with ectopia, with agreement levels ranging from 0.91 to 0.97 (Table II). Intrarater agreement was also excellent for the proportion of the cervix with ectopia, with levels ranging from 0.85 to 0.89. Interrater agreement was also extremely good, although lower than intrarater agreement levels. The interrater agreement level for the absolute area of ectopia was 0.83 (for both measures). Interrater agreement for the proportion of the cervix with ectopia was 0.68 as measured by the intraclass correlation coefficient and 0.68 as measured by weighted κ.

We also compared clinician assessment with the computer planimetry technique for the measurement of the proportion of the cervix with ectopia. Because the computer planimetry technique is able to measure minute areas of ectopia, we considered areas of the cervix rated as <10% by computer planimetry to be equivalent to the
category rated as "none" by clinician assessment. The distributions of women with large proportions of the cervix with ectopia were similar for the 2 measurement techniques. For example, both measurement techniques categorized 8% of women as having 25% to 50% of the cervix covered with ectopia, and both categorized about 6% of women as having ectopia covering >50% of the cervix (Table III). However, measurement of ectopia by computer planimetry resulted in more women with no ectopia or very small ectopia (<10% of the cervix with ectopia) than did clinician assessment; 67% of measurements by computer planimetry fell into this category versus 59% by clinician assessment.

Overall levels of agreement between ectopia measurements made by clinician assessment and computer planimetry were moderate ($k = 0.49$; Table IV). Agreement levels were higher when computer planimetry was compared with assessments by a single clinician (Susan Zdenek) responsible for 54% of the measurements ($k = 0.52$) than when computer planimetry was compared with a group of 8 other clinicians, each of whom made far fewer assessments of ectopia ($k = 0.44$).

We also considered agreement levels stratified by the area of ectopia for the computer planimetry method. In general, we found that agreement levels were higher for women with large areas of ectopia than for women with small areas of ectopia. For example, intrarater and interrater reliability levels were 0.95 and 0.89, respectively, for women with areas of ectopia $>$20.5 cm$^2$ but were 0.79 and 0.62, respectively, for women with areas of ectopia $<$0.15 cm$^2$. We also found higher intrarater agreement levels when the relative area of ectopia was larger ($\geq$15% of the cervix) than when the relative area of ectopia was smaller ($<5$% of the cervix; 0.85 vs 0.42). However, this did not hold true for the interrater reliability for the relative area of ectopia, where agreement levels were lower for categories corresponding to larger amounts of ectopia ($\geq$15% of the cervix) than for categories corresponding to smaller amounts of ectopia ($<5$% of the cervix; 0.72 vs 0.77).

Comment

We found high levels of agreement in measuring cervical ectopia by computer planimetry and by clinician assessment. In particular, the computer planimetry method had excellent levels of both intrarater (0.86-0.97) and interrater (0.68-0.85) agreement for measurements of both the absolute and the relative areas of cervical ectopia. Levels of agreement between computer planimetry and clinician assessment for measurement of the relative area of ectopia were moderate (0.48).

Our results agree with the previous study by Gilmour et al.$^{22}$ who also measured the intrarater and interrater reliabilities of the relative area of cervical ectopia by computer planimetry and visual assessment methods. For example, for computer planimetry, they found intrarater and interrater agreement levels of 0.85 and 0.82, respectively. For intrarater and interrater reliability of visual assessment after application of acetic acid, they found agreement levels of 0.77 and 0.72. They found somewhat higher levels of agreement between visual assessment and computer planimetry than we did (0.69 vs 0.48), although this may have been because their visual assessment technique was conducted with slides projected onto a screen, as opposed to a naked eye assessment during a clinical examination in our study.

In a strict sense this study was limited to an assessment of the reliability (consistency) of cervical ectopia measurements by the two techniques. To assess the validity of the two techniques we would need a criterion standard measure by which to judge the techniques. Because of the high reliability levels for computer planimetry in this study and the higher reliability levels for computer planimetry than for clinician assessment in previous studies,$^{22}$ however, one might conclude that computer planimetry appears to be the more valid measurement technique. Moreover, a reader making a computer-assisted measurement from a photograph should be able to make a more accurate assessment than a clinician who rapidly assesses ectopia with the naked eye and then must complete the physical examination before recording the measurement.

Nevertheless, in clinical practice it will generally not be feasible to use computer planimetry to assess cervical ectopia. If not, then application of 4% to 5% acetic acid before un magnified visual assessment of ectopia has been shown to enhance the reliability of visual assessment.$^{22}$ Because of the moderate levels of agreement between measurements made by computer planimetry and clinician assessment techniques and the fact that the agreement level was higher when limited to measurements made by a single, experienced clinician, we believe that properly trained clinicians should be able to identify women with moderate to large amounts of cervical ectopia. Providing clinicians with model images of the cervix with various levels of ectopia outlined (eg, none,
25%, and 50% ectopia as measured by computer planimetry, periodic updating of training, and training clinicians to report their ectopia ratings aloud during the course of the physical examination (to act as a mnemonic for later recording) may result in more accurate clinical assessments.

Most previous studies of cervical ectopia have measured ectopia as a percentage of the ectocervix. As part of our study assessing the role of hormonal contraception and cervical ectopia in the acquisition of cervical infections, however, we hypothesized that the absolute area of columnar epithelium exposed to an infectious agent may be more important than the proportion of the cervix covered by columnar epithelium. For this reason we assessed the intrarater and interrater reliabilities of computer planimetry measurements for the absolute area of ectopia in addition to the proportion of the cervix with ectopia. We found that both intrarater and interrater reliabilities were generally higher for measurements of the absolute area of ectopia than for measurements of the proportion of cervix with ectopia. This finding is not unexpected, because our measurements of the proportion of the cervix with ectopia depended on measuring the diameter of the cervix in addition to the area of the cervix with ectopia. Moreover, both raters who used computer planimetry (Irina Yacobson and Charles Morrison) reported that accurate measurement of the diameter of the cervix was generally more difficult than accurately outlining the area of ectopia. This was either because of obstruction of the view of a part of the cervix by the vaginal fornices or because of the difficulty of measuring a diameter when the shape of the cervix was irregular. Thus the absolute area of ectopia may be the more appropriate measure to use in studies assessing the role of cervical ectopia in disease transmission.

Use of the vinyl dot was particularly helpful in assessing the absolute area of ectopia. Another group has measured the absolute area of ectopia by using a camera with a fixed focal length and preadjusted settings, but these measurements were based on trigonometric calculations and the assumption that the image was taken at an exact right angle to the cervix. In contrast, the vinyl dot allowed individualized scaling independent of focal length and trigonometric principles. We believe that use of the dot thus allows more accurate measurement of the absolute area of ectopia and will allow us to examine in a longitudinal study the role of cervical ectopia in the acquisition of cervical infections.

Other strengths of this study include the relatively large numbers of measurements that were analyzed, our ability to consider both intrarater and interrater reliabilities, and our ability to assess the reliability of measurements of both the absolute area and the proportion of the cervix with ectopia. Also important were the comparisons between measurements made by clinical assessment with those made by computer planimetry. The diversity of our study population in terms of age and ethnic composition supports the generalizability of our findings.

Weaknesses of this and other studies of cervical ectopia relate to the fact that because ectopia is measured during a speculum examination, the degree to which the blades of the speculum are opened may affect the area of visible columnar epithelium. Moreover, as noted in previous studies that used computer planimetry, use of a 2-dimensional photograph to measure physiologic aspects of a 3-dimensional structure (the cervix) may bias the measurement in unknown ways. Finally, we did not exclude the area of the cervical os from our ectopia measurements, as some other studies have done. We did this because we considered that the os generally represented a very small area and that excluding the area of the os would not make an important difference to our findings. We also believed that if the os were open (with associated visible columnar epithelium), then all visible columnar epithelium should be measured. However, we acknowledge that our ectopia measurements may be slightly higher (particularly among parous women) than those in studies that exclude the area of the cervical os from cervical ectopia measurements.

In this study we found high levels of both intrarater and interrater reliability for cervical ectopia measurements made by computer planimetry. This suggests that measurement of cervical ectopia by computer planimetry is appropriate to the examination of the role of cervical ectopia in disease occurrence. The moderate levels of reliability between clinical assessment of ectopia and com-

### Table IV. Measure of agreement and 95% confidence interval for proportion of cervix with ectopia measured by computer planimetry and clinician assessment methods

<table>
<thead>
<tr>
<th></th>
<th>Weighted k for proportion of cervix with ectopia</th>
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<tbody>
<tr>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Computer planimetry versus clinician 1</td>
<td>964</td>
</tr>
<tr>
<td>Computer planimetry versus other clinicians</td>
<td>425</td>
</tr>
<tr>
<td>Computer planimetry versus all clinicians*</td>
<td>929</td>
</tr>
</tbody>
</table>

*Includes 9 clinicians who made 200 ectopia measurements each.
puter planimetry suggest that clinical assessment of ectopia may be useful when measurements by computer planimetry are not feasible.

We thank Dr. Jay Baker and Ms. Kathleen Arbogast of the CONRAD Clinical Research Center at Eastern Virginia Medical School for their help in identifying use of the vinyl dots for calibration of cervical ectopia measurements. We also thank the clinical and administrative staff of Planned Parenthood of Maryland for their contributions to the study.

REFERENCES