A Digital Framing Ring for Stabilizing Cervix Location in Digital Cervicography Images

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Abstract

Objective: Visualization and digital documentation are critical to many cervical cancer programs worldwide. Practitioner competency remains a major limitation for visualization-based programs. High variability in image quality (cervix positioning and sharpness) is common between practitioners. To improve image quality on the smartphone-based Enhanced Visual Assessment (EVA) System, a framing ring designed to guide the user to properly position and scale the cervix within the image was inserted into the app. In this paper, the effects of the framing ring on cervix position and sharpness in digital cervicography images were quantitatively analyzed. **Methods:** The framing ring was developed as a smartphone feature on the EVA System app. Anonymized images from MobileODT's image portal acquired with and without the framing ring feature were selected. Comparisons were made in proper framing of the cervix, and in two measurements of image sharpness – a calculated Brenner score and manual labeling. **Results:** Altogether, 911 images without the framing ring were analyzed, of which 695 (76%) were judged as well-framed. The mean Brenner and manual scores were 3.39 and 1.12, respectively. 174 images with the framing ring were analyzed, of which 159 (91%) were judged as well-framed. The mean Brenner and manual scores were 4.18 and 1.66, respectively. **Conclusions:** Cervix localization and sharpness remain challenges in digital cervicography. The framing ring has the potential to address cervix localization and sharpness in the images. In time this feature, in combination with other methods, could improve the performance of the EVA system as a tool for quality control in digital cervicography and developing machine learning algorithms of cervical pathology in images.

Introduction

Visual inspection with acetic acid (VIA) is commonly used in cervical cancer screening. Digital imaging of the cervix (digital cervicography) can improve the efficacy of cervical cancer screening by enabling image recognition applications, remote consultations and effective training [1].

The Enhanced Visual Assessment system (EVA, Figure 1) is used for digital cervicography in over 20 countries. The system consists of a mobile phone running the CervDX Android app, a magnifying lens and a light source. While assuring patients confidentiality, images collected with the EVA system are used for quality assurance, remote consultation and for developing machine learning algorithms for automatic risk score calculation.

In some settings the quality of the cervical images captured with the EVA system is low and can limit the ability to use the images for said purposes. The majority of image quality issues concern the sharpness (due to poor focus) and the framing of the cervix within the image. While the motion blur problem is manageable by using a stand, focus and framing of the image remain an unsolved challenge.

As one way to address these issues we developed the framing ring feature, a static ring displayed on the EVA screen, which guides the user to the proper framing of the cervix. A properly framed cervix—in which the cervix fills a significant portion of the display but is not cropped—is also easier to focus on. The framing ring also fixes the working distance and, with a one-time focus pre-set, can further assure in-focus images.

We introduced the framing ring feature to two nurses that were using the EVA system in Thika, Kenya. Captured images were compared to images that were taken before the feature was introduced and to images taken by four different nurses in the same organization that were captured without the framing ring feature (overall images taken by six nurses were collected). Framing and sharpness of the images were evaluated by two and three reviewers, respectively. We also calculated the Brenner focus measure of each image, a common technique used to measure the sharpness of an image[2].

Methods

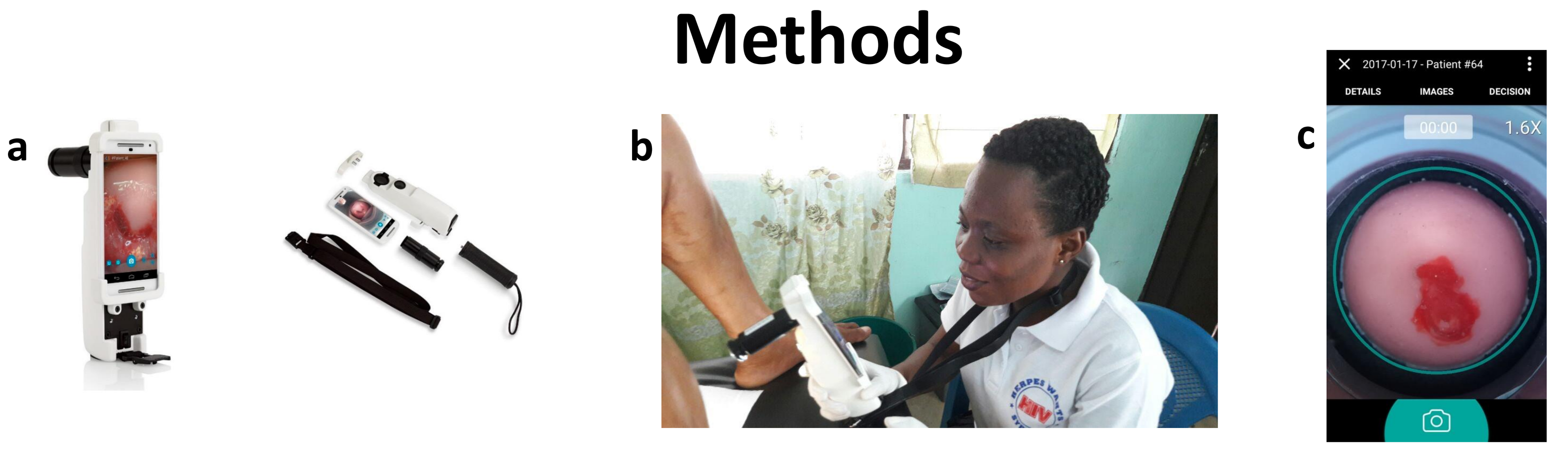

Figure 1: (a) The EVA system and its components: a mobile phone, a light source, a lens and a neck strap. (b) EVA system being used in a field clinic. (c) The framing ring on the CervDx app.

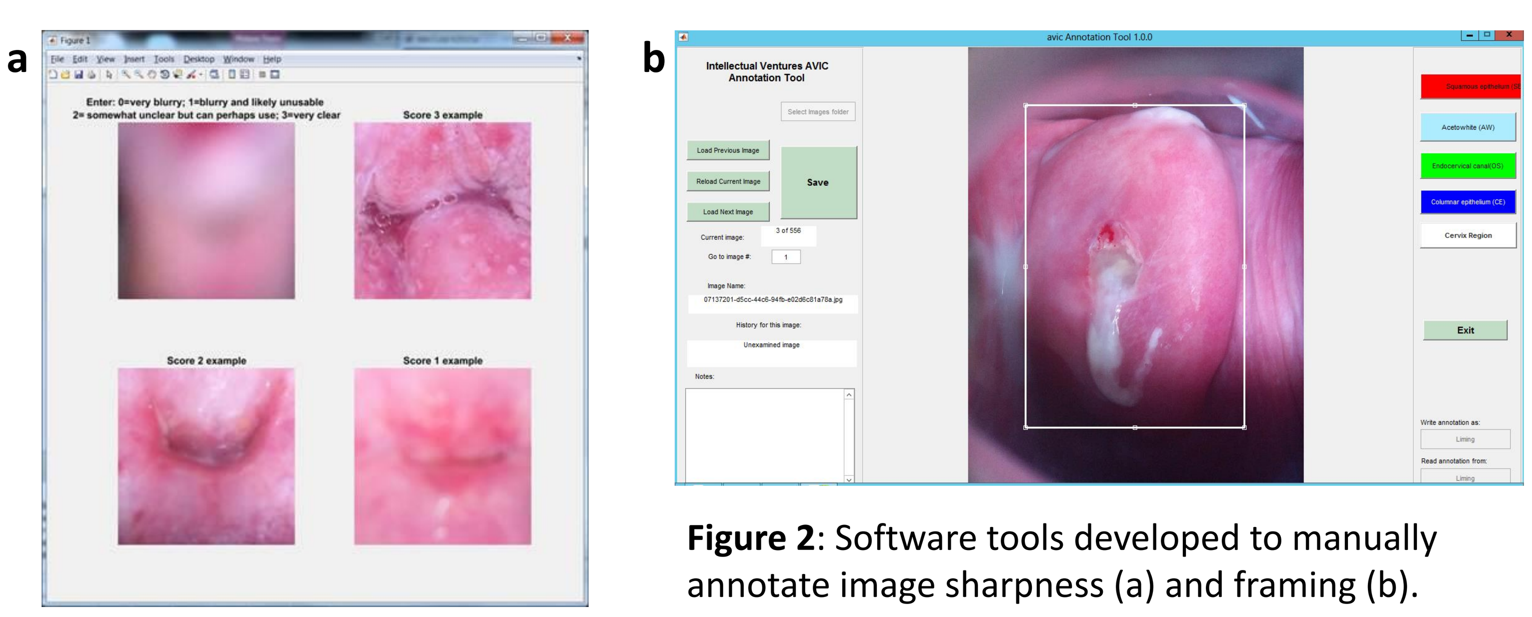

Figure 2: Software tools developed to manually annotate image sharpness (a) and framing (b).

Deployment and Data Collection

Six nurses with experience using the EVA system were recruited for the experiment. We activated the framing ring feature for two of the nurses, and collected images from three months before the feature activation to three months after. After eliminating non-cervix images (e.g. images of the cryo tip captured during cryotherapy), we analyzed 1085 images, of which 174 were taken with the framing ring.

Analysis

We evaluated each image for sharpness and whether the cervix was framed within the image. Annotators were shown the images in random order and were blinded as to whether the framing ring was used.

An annotation tool (Figure 2a) was used to manually score the sharpness of images on a scale of 0 ("very poor") to 3 ("excellent"). Images with scores 2 and 3 are considered to be eligible for digital evaluation. The Brenner score was also calculated for each image, which correlates fairly well with the manual scores. A second tool (Figure 2.b) was used to mark the cervix region in the image, as well as to note whether the entire cervix was properly framed within the image (i.e. not clipped). These scores and annotations were analyzed to compare the quality of images captured with and without the framing ring.

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Results

Effect on Image Sharpness

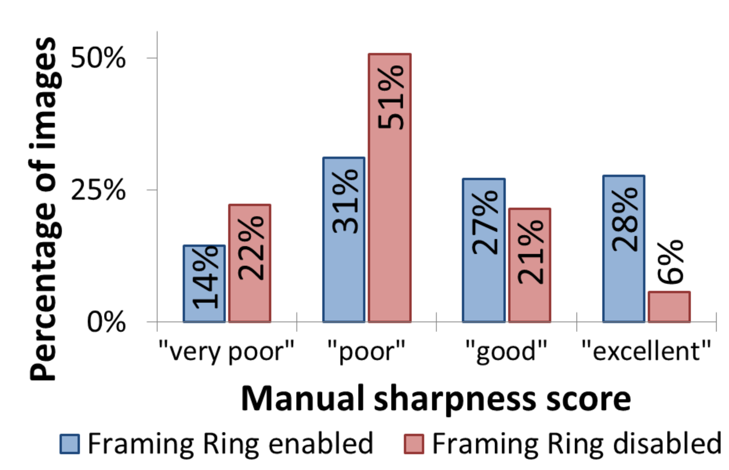

Figure 3: Histograms of manual sharpness scores for images captured with and without the framing ring, showing significant improvement with the framing ring.

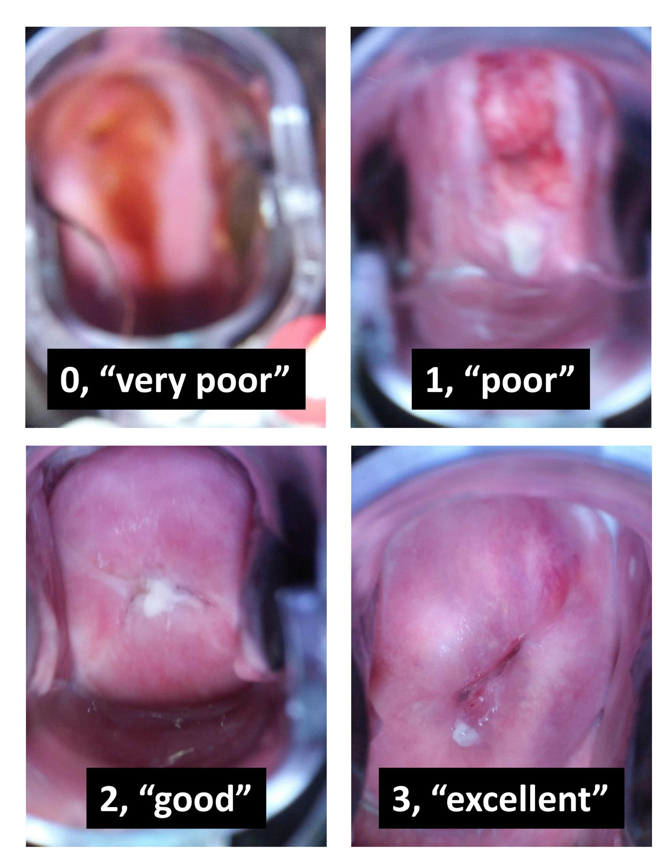

Figure 4: Example images representing each manual sharpness score.

Effect on Framing

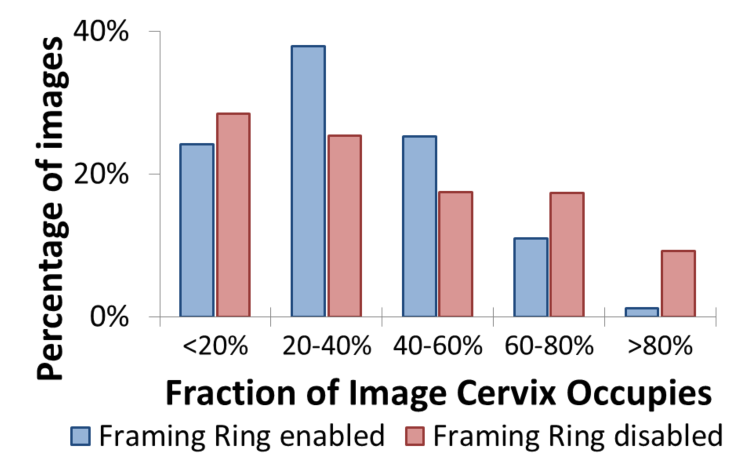

Figure 5: Histograms of the scale of the cervix in images captured with and without the framing ring. Clipping becomes a concern at scales greater than 60%. At very low scales the likelihood of focusing on regions outside of the cervix increases. The distribution of cervix scale is narrower with the framing ring.

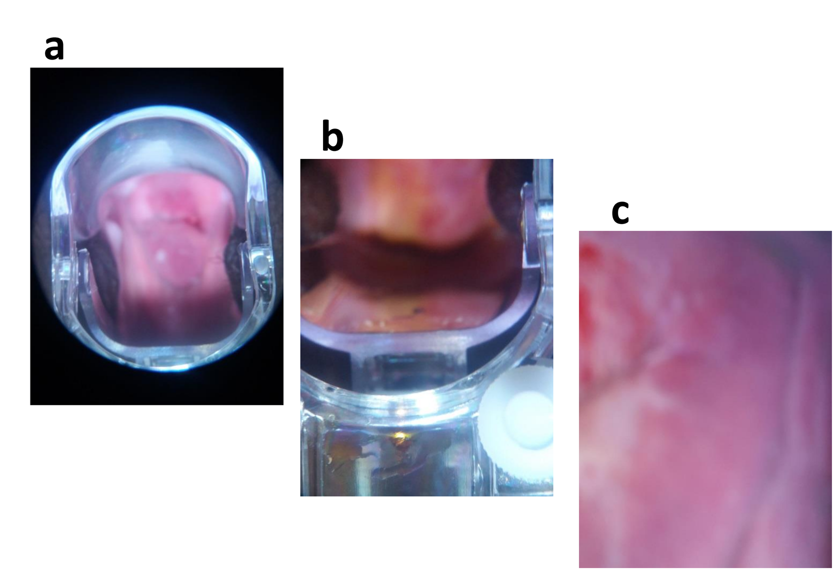

Figure 6: Examples of poor framing. (a) The cervix occupies only a small portion of the image. (b) The cervix is clipped despite being at an appropriate scale. (c) The cervix is clipped due to too large of scale.

Summary of Key Metrics

	Without framing ring	With framing ring
Average manual sharpness score	1.12 (±0.75)	1.66 (±0.94)
Average Brenner score	3.39 (±3.16)	4.18 (±2.99)
Sufficiently sharp images[1]	27%	54%
Cervix sufficiently in frame [2]	76%	91%
Average cervix scale [3]	42% (±27%)	35% (±20%)
High-quality images[4]	**22%**	**52%**

[1]Median manual score ≥ 2, "good."
[2]Judged as not being cropped to an extent that may impact evaluation.
[3]Percentage of image occupied by cervix. The framing ring occupies 50% of the image.
[4]Cervix sufficiently in frame and median manual score ≥ 2.

Discussion and Conclusion

The improvements in framing and sharpness are statistically significant ($p<.0001$, based on Mann-Whitney U test[3]) and are significant in impact (more than doubling the percentage of usable images). The effect was similar whether comparing the same nurse's performance with and without the framing ring or comparing between nurses of similar experience who either used or didn't use the framing ring. This suggests that the image quality improvement which the framing ring enhances is independent of a specific user.

We continue to improve the EVA system in order to further increase the proportion of high-quality images captured. In-progress developments involve real time image quality feedback for the user, based on a machine learning model that incorporates the Brenner score together with additional image features. Further developments are planned to use the high-quality images for the development of machine learning algorithms for automatic risk score calculation.

References

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