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Remote quality assurance in cervical cancer screening in low resource settings using a handheld smartphone-based colposcope

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ABSTRACT

Cervical cancer is a leading cause of cancer death for women all across the developing world, where much of the infrastructure required for effective cervical cancer screening is unavailable because of limited resources. One of the most common method to screen for cervical cancer is by visual inspection with acetic acid (VIA), in which the cervix is imaged with the naked eye. Given inherent challenges in analysis and documentation when characterizing cervical tissue with the naked eye, an optical solution is needed. To address this challenge, a smartphone was modified and transformed into a mobile colposcope (a device used to image the cervix from outside) by adding a custom-fit light source and optics. The mobile smartphone colposcope was designed such that it augments VIA and easily integrates within the standard of care. The mobile smartphone colposcope is controlled by an app, which, stores cervical images captured on the mobile smartphone colposcope on a portal, enabling remote doctors to evaluate images and the treatment chosen by the health worker. Images from patients undergoing cervical cancer screening by a nurse using VIA in the University Hospital of Mirebalais (HUM) GYN outpatient clinic in Haiti were captured on the mobile smartphone colposcope. These images were later analyzed by an experienced OB/GYN at HUM, who determined whether or not the patient should be treated with cryoablation; more complicated cases were also shared with a consulting doctor in the US. The opinions of the experienced OB/GYN doctors at HUM, as well as the experts from the US, were used to educate nurses and midwives performing mobile colposcopy. These results suggest that remote assessment offered by mobile colposcopy can improve training of health workers performing VIA, and ultimately affect the therapy administered to patients.

Keywords: smartphone imaging, colposcopy, low-resource settings

1. INTRODUCTION

Cancer is now the leading cause of death worldwide[2]. Cervical cancer is the third most frequent cancer after breast and colorectal cancer[1]. It is the second most frequent cancer among women and ranks fourth in mortality[1]. The following statistics can give us an idea of the impact it has in the lives of women. For example: 529,800 new cases are detected each year with 275,100 annual deaths caused by cervical cancer[1]. Poverty determines health in the development of this disease, as poor populations lack access to health care[3,4]. In Haiti, where the root cause of poverty is structural violence, screening for cervical cancer is met with numerous challenges. In Haiti, The incidence of cervical cancer is: 93/100,000, the highest in the Caribbean[5].

Having access to transportable and less expensive methods for screening plays a vital role in the public health approach to this problem. The critical instrument for diagnosing cervical cancer is the colposcope, a device used to image the cervix from outside the body. It's for these reasons that University Hospital of Mirebalais (HUM) Women's Reproductive Health Services began testing a mobile smartphone colposcope to assist in the screening for cervical cancer. The goal of this article is to show how to integrate a mobile smartphone colposcope into the workflow of screening for cervical cancer in low-resource and under-served areas as part of broader public health and global health programs.

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This paper will cover some of the advantages of the mobile smartphone colposcope, as well as challenges that remain to be addressed while using the device in a low-resource setting. The paper will focus on: mobility of the device, imaging, and teaching capabilities.

2. METHODS

2.A. The Mobile Smartphone Colposcope

The Mobile Smartphone Colposcope is a smartphone attached to additional hardware and an integrative app that enable colposcopic imaging. Details of the mobile smartphone colposcope are given elsewhere[6]. Specifically, the hardware added consists of a white LED light source, a protective case, a handle, and a lens that enables imaging at a working distance and magnification similar to those used in colposcopy. In this initial pilot, a first generation Moto G phone (Motorola) was used. The case and handle were 3D printed using a uPrint SE printer at Boston University's Center for Future Technologies in Cancer Care (Boston, MA). The LED source consists of a star LED coupled to an LED collimating lens (LEDSupply). In addition to this hardware, an image capture software running for Android phones was developed and installed on the device. The software also enabled importing and cataloguing images according to patient ID, time stamp, and GPS coordinates. The bill of materials for the smartphone colposcope was under $ 1000, including the phone. By comparison, the traditional optical colposcope that is generally used is much more expensive, priced at $10,000 to $14,000 in the US.

While cell phone cameras have been used for cervical imaging as part of cervicography, the Mobile Smartphone colposcopes represent, to our knowledge, the first attempt at optically upgrading a smartphone and adapting it for colposcopy. In the current study, a prototype version of the mobile smartphone colposcope was used.

2.A. Mobility

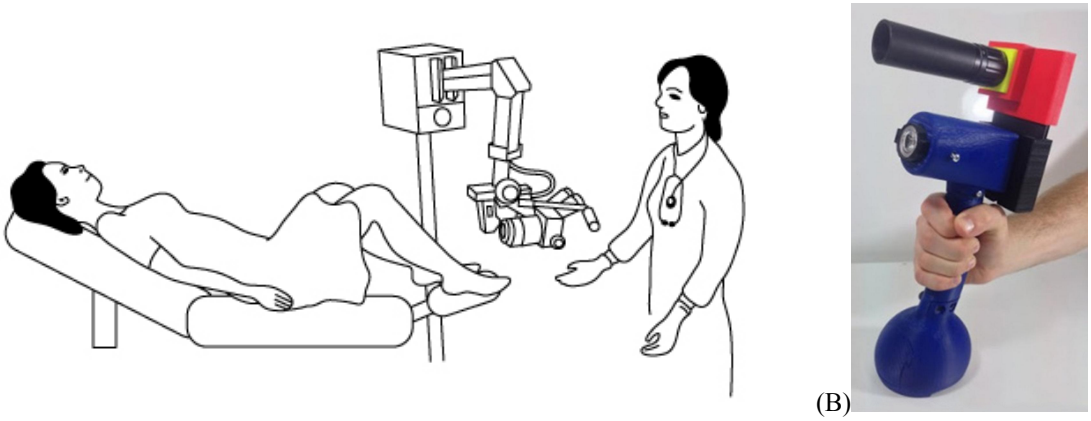
The conventional colposcope consists of a mounting pole, an arm, and a colposcope head with optics and binoculars. As such, they are difficult to transport. They are significantly larger and heavier than the handheld mobile smartphone colposcopes, and take up much more space. Thus it is impossible for a single person to carry a conventional colposcope. These are limiting factors to consider when conducting a mobile clinic outreach screening program for cervical cancer, as it is simply not feasible to transport a traditional colposcope to the remote clinic. Using a mobile smartphone colposcope for these purposes is far easier and more convenient. A comparison is shown in Fig. 1. Additionally, the mobile smartphone colposcope takes up far less space in the clinic than the conventional colposcope.

2.C. Imaging

Considering the images taken with the smartphone, qualitatively, there is not much noticeable difference between a mobile smartphone colposcope and a conventional colposcope. A quantitative comparison is given elsewhere[6]. When an exam is performed the images can be magnified both using different optical lenses and on the screen. A comparison of the optics of the mobile smartphone colposcope and a traditional colposcope can be seen in Figures 2a, 2b and 3a, 3b and 3c. A green filter is also available for use as in a conventional colposcope to illuminate vasculature problems. Lastly, while performing an exam, the mobile smartphone colposcope has been found to outperform conventional colposcopes in its ease of use.

2.D. Teaching capabilities

One advantage that quickly becomes obvious when using the mobile smartphone colposcope is the ability to electronically share images with other clinicians. The advisers can then provide expertise in the analysis and diagnosis of disease to those learning to perform colposcopic exams. It also provides a format for professors and advisors to perform quality control from a distance. These aspects favor a long-term long distance teaching program. It is additionally possible to share the images with the patient for explanation if necessary. Lastly, a projection screen can be used to project images during the exam for teaching purposes.

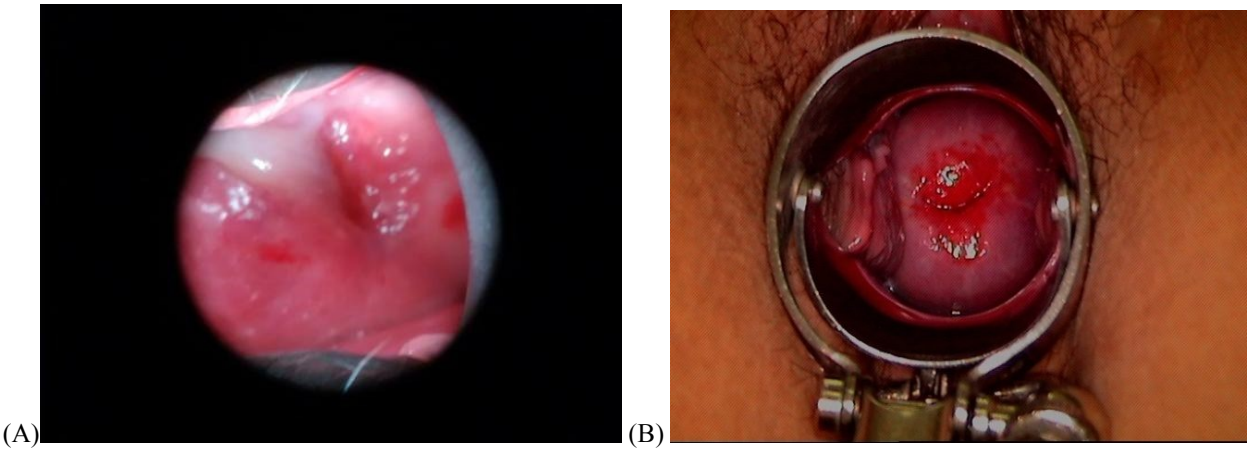


(A) (B)

Fig. 1: Comparison of traditional, stationary colposcope standing between the patient and doctor (A), and the handheld Mobile Smartphone colposcope (B).

3. RESULTS AND DISCUSSION

The Mobile Smartphone Colposcope is cheaper, easier to transport when compared to the conventional colposcope, and it provides good imaging, which is useful for teaching and training purposes.



(A) (B)

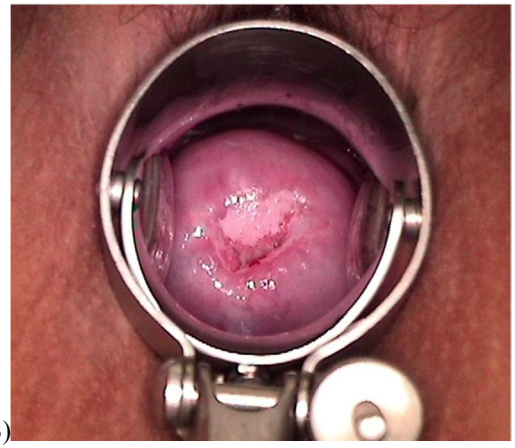
Fig. 2: (A) Normal cervix, imaged using the Mobile Smartphone Colposcope. (B), Normal cervix imaged using a traditional colposcope.

The Mobile Smartphone Colposcope has a public health impact potential in facilitating access to and screening for cervical cancer in low-resource countries and underserved areas of developed countries. This device and technology provide a unique opportunity to significantly change teaching and training opportunities in global health whereby distance teaching and quality control measures can be put in place very easily. In Haïti, where there is lack of trained providers in colposcopy, this teaching opportunity has already had an impact in the Women's Health Services Department at HUM. International professors have assisted our staff in reading and analyzing images taken with the colposcope.

The only inconvenience that has been noted is the importance of access to the Internet when using the device. Internet accessibility for sharing images isn't always available in poor resource settings. However, this problem can be easily overcome using a national SIM card, as many of the remote clinics nonetheless have access to 3G cell phone coverage.

4. CONCLUSION

The Mobile Smartphone Colposcope has the potential to have a significant impact in the public health and global health approaches to cervical cancer screening. This is a revolutionary step in the access it will provide in disease detection strategies to reduce mortality and morbidity due to cervical cancer, specifically in resource – poor settings. However, this study was preliminary, and larger studies are needed for more conclusive, quantitative results. Additionally, new studies should be carried out to provide evidence on the impact potential in settings with more resources.

(A)  (B) 

(C) 

Fig. 3: (A) Abnormal cervix, treated using the Mobile Smartphone Colposcope. (B) Abnormal cervix, imaged using a traditional Colposcope. (C) Abnormal cervix imaged using Mobile Smartphone Colposcope.

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