Low-Cost Instructional Apparatus to Improve Training for Cervical Cancer Screening and Prevention

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BACKGROUND: Cervical cancer remains one of the leading causes of cancer for women in medically underserved areas. This is in part due to a lack of trained clinicians to provide the necessary diagnosis and treatment of precancerous lesions to prevent cervical cancer. Increasing medical provider knowledge and skills is important for the early detection and prevention of cervical precancer and cancer in medically underserved areas of the United States and globally.

METHOD: LUCIA is a low-cost, universal cervical cancer instructional apparatus that can be used to teach and practice a variety of essential skills for cervical cancer screening, diagnosis, and treatment, including: visual inspection with acetic acid, Pap and human papillomavirus DNA specimen collection, colposcopy, endocervical curettage, cervical biopsy, cryotherapy, and loop electrosurgical excision procedure.

EXPERIENCE: LUCIA was used to provide hands-on training in six courses held in Texas (n=3), El Salvador (n=1), and Mozambique, Africa (n=2). Standardized provider evaluations were administered at three of these courses and resulted in mean scores of 4.12/5 for usefulness, 4.46/5 for skill improvement, and 4.43/5 for ease of skill evaluation.

CONCLUSION: LUCIA provides dynamic, real-time feedback that allows trainees to learn and practice important skills related to cervical cancer prevention while simulating a patient exam.

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Cervical cancer is preventable; however, it remains one of the leading causes of cancer-related death among women in low- and middle-income countries.[1] Although cervical cancer incidence has decreased in high-income countries owing to the implementation of screening programs, cervical cancer rates remain elevated in poor and medically underserved communities.[2]

A number of tools are available for the early detection and treatment of cervical cancer and its precursors in low-resource settings. Screening tests

Table 1. Skills Trained Using Common Cervical Cancer Training Models Compared With LUCIA

	Plastic Mannequin (eg, ZOE Model)	Jhpiego Flashcards	Animal Tissue Model	LUCIA
Skill taught				
Speculum insertion	✓	X	X	✓
VIA	✓	✓	X	✓
Pap and HPV sample collection	✓	X	X	✓
Endocervical swab and ECC	✓	X	X	✓
Colposcopy	✓	X	X	✓
Cervical biopsy	X	X	✓	✓
Cryotherapy	X	X	✓	✓
LEEP	X	X	✓	✓
Commercially available	✓	✓	✓	X
Cost ($)	600–2,700	0, available online	56	47

✓, can be practiced or applicable to model; X, cannot be practiced or not applicable to model; VIA, visual inspection with acetic acid; HPV, human papillomavirus; ECC, endocervical curettage; LEEP, loop electrosurgical excision procedure.

include Pap and human papillomavirus (HPV) testing as well as visual inspection with acetic acid.[3] Depending on the setting, patients who screen positive undergo further testing with colposcopy and biopsy or immediate treatment using cryotherapy or a loop electrosurgical excision procedure (LEEP) to remove precancerous lesions and prevent progression to invasive cancer. These clinic-based procedures provide a cost-effective means of preventing cervical cancer.[4,5] Unfortunately, medically underserved areas lack sufficient numbers of trained providers, in part due to limited opportunities for hands-on training.[6]

There are commercially available mannequins to help teach cervical cancer screening skills, but these simulators are costly for use in low-resource settings (Table 1). Low-cost options include flashcards developed by Jhpiego to teach providers to recognize lesions during visual inspection with acetic acid.[7] To practice biopsy, cryotherapy, and LEEP, animal tissue is often used (eg, beef tongue), but these models do not integrate the ability to teach screening, detection, and treatment skills.

METHOD

We developed and evaluated LUCIA (Low-cost Universal Cervical cancer Instructional Apparatus), a low-cost cervical cancer training model ($47) that can be used to provide hands-on training for all of the necessary skills related to cervical cancer prevention.

LUCIA is a portable simulation model designed to act as a hands-on teaching aid for clinician education. LUCIA allows trainees to practice cervical cancer screening, diagnosis, and early treatment techniques while simulating a gynecologic exam (Fig. 1). LUCIA consists of a wooden pelvic frame, a vaginal canal (made from polyvinyl chloride pipe, waterproof fabric, and foam), cervical model holders, and a variety of cervical models. There are two cervical model holders: a stationary holder and a holder

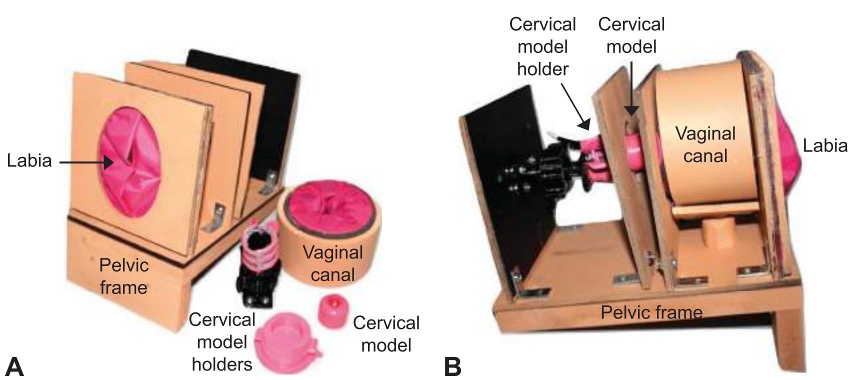

Fig. 1. Front (**A**) and side (**B**) view of the LUCIA model.

Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

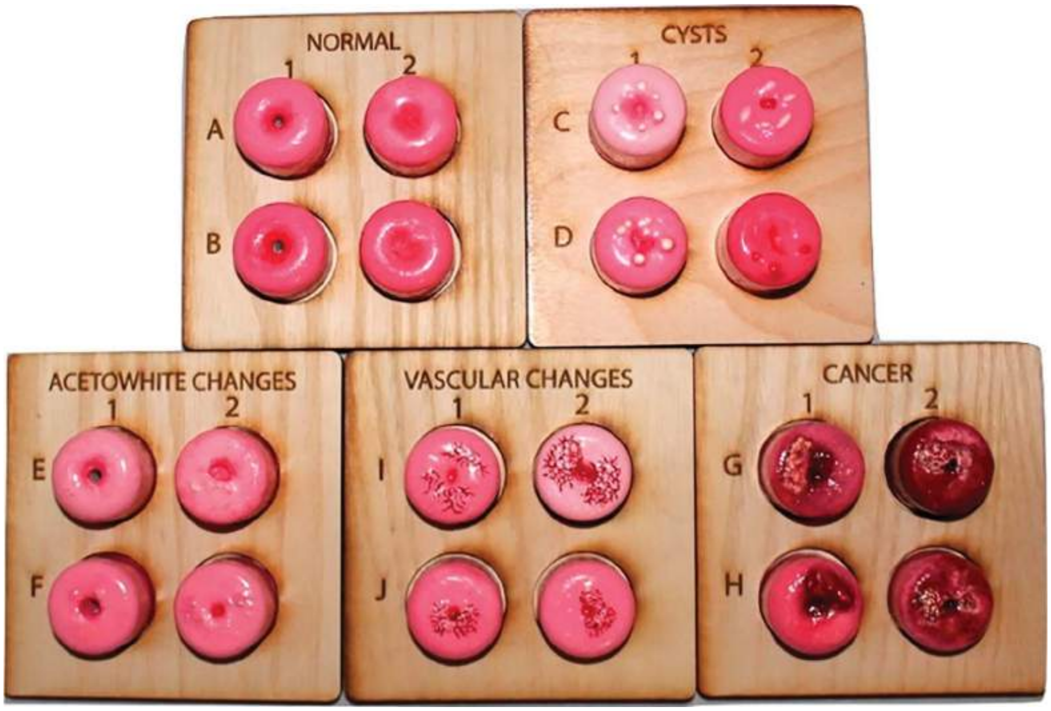

Fig. 2. Image of a complete set of reusable three-dimensional printed cervical models.
Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

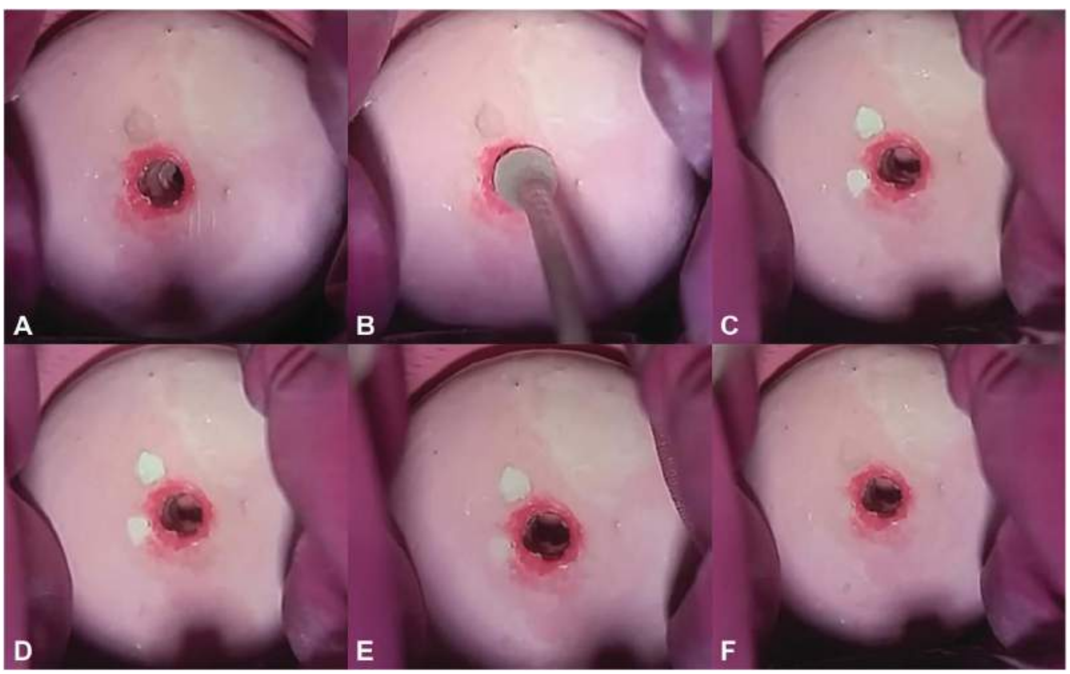

Fig. 3. Image of one of the low-grade precancer cervical models inside the pelvic frame of LUCIA before (**A**), during (**B**), and after (**C–F**) hot water is applied during a simulated visual inspection with acetic acid procedure. The appearance of white lesions after hot water is applied simulates a positive visual inspection with acetic acid result. Five seconds after (**C**), 1 minute after (**D**), 2 minutes after (**E**), and 3 minutes after (**F**).
Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

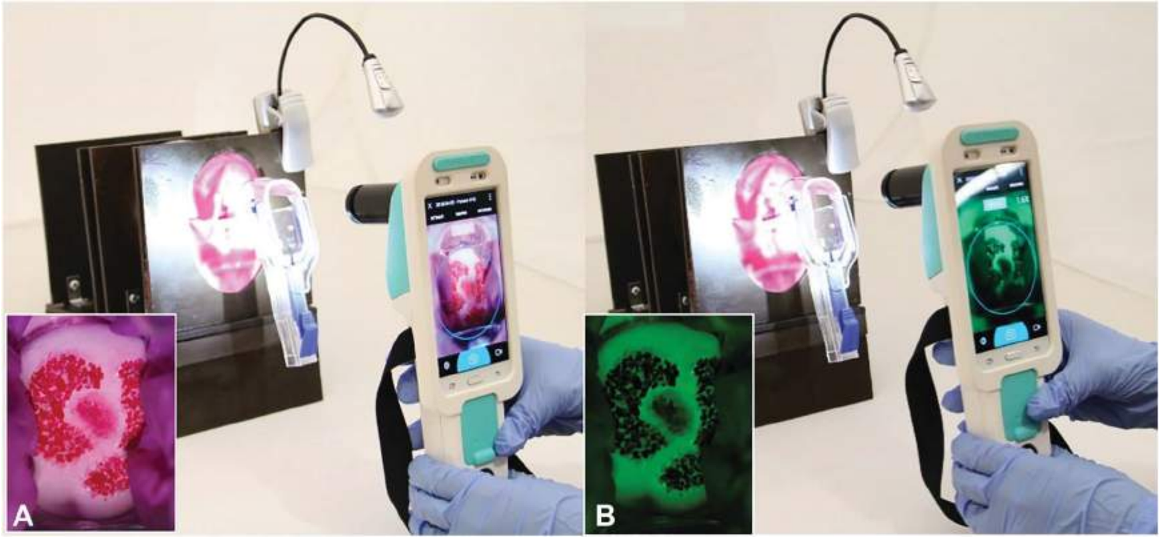

Fig. 4. Images of LUCIA being used for colposcopy practice. A mobile colopscope (mobileODT) is used to visualize the cervical model inside the pelvic frame with (**B**) and without (**A**) a green filter applied.

Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

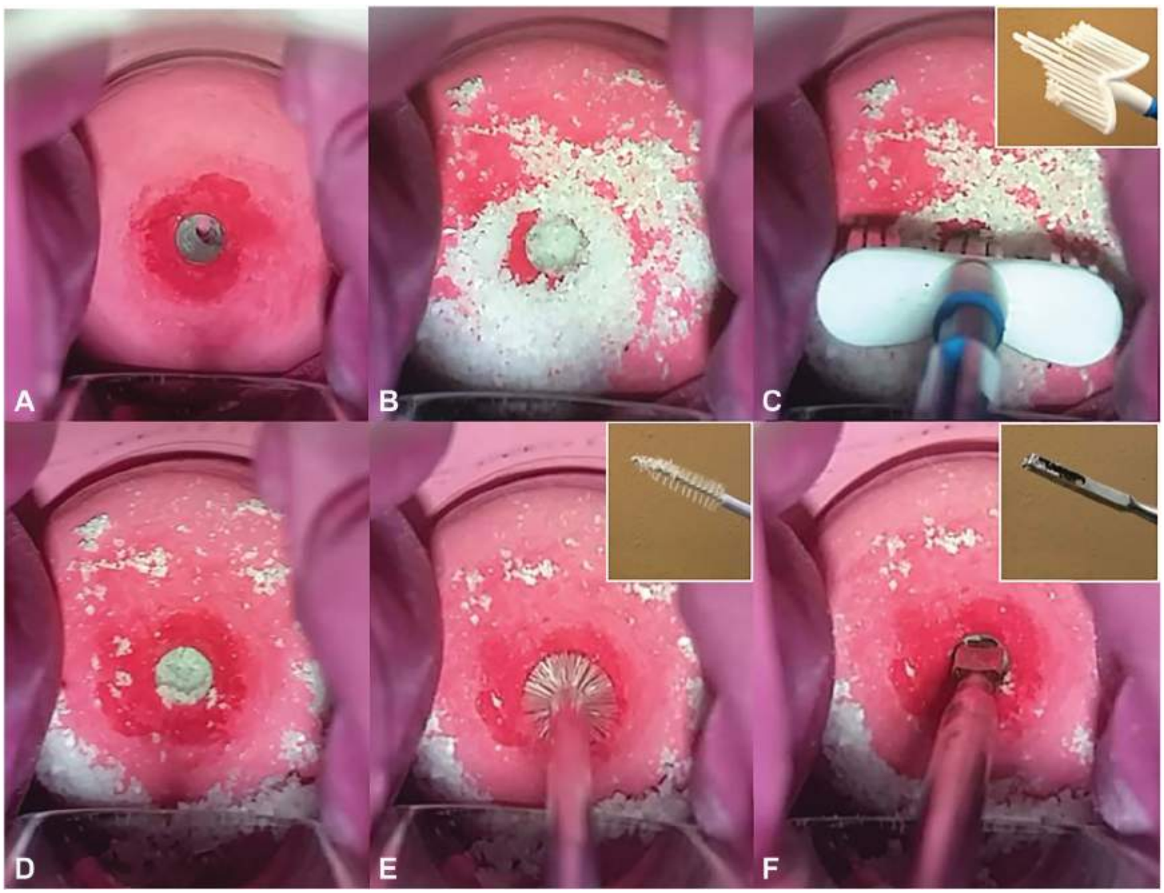

Fig. 5. Image of cervical model inside the pelvis of LUCIA being used for Pap test, human papillomavirus (HPV), and endocervical swab collection and endocervical curettage training. Insets show instruments after use. Before applying corn flour (**A**), after applying corn flour (**B**), during Pap test and HPV collection (**C**), after Pap test and HPV collection (**D**), endocervical swab (**E**), and endocervical curettage (**F**).

Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

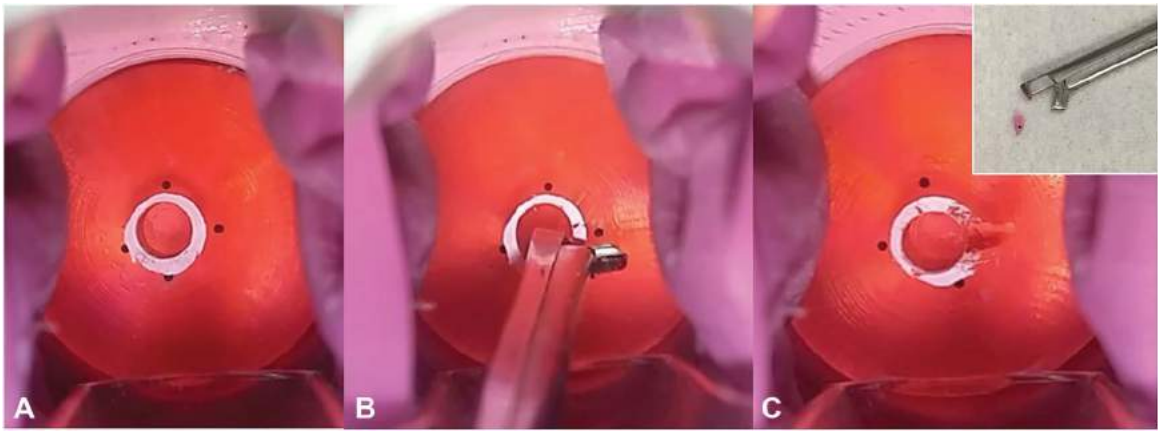

Fig. 6. Images of biopsy gel cervical model inside the pelvic frame of LUCIA before (**A**), during (**B**), and after (**C**) a cervical biopsy is taken. The *pink ring* in the center of the model represents the squamocolumnar junction. Inset image shows biopsy containing the removed black bead.

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with a rotating arm attached to a small clamp. The cervical model holder with a small clamp is lined with aluminum foil so that a conductive current can pass through when practicing LEEPs. Both allow different cervical models to be interchanged so trainees can practice different skills.

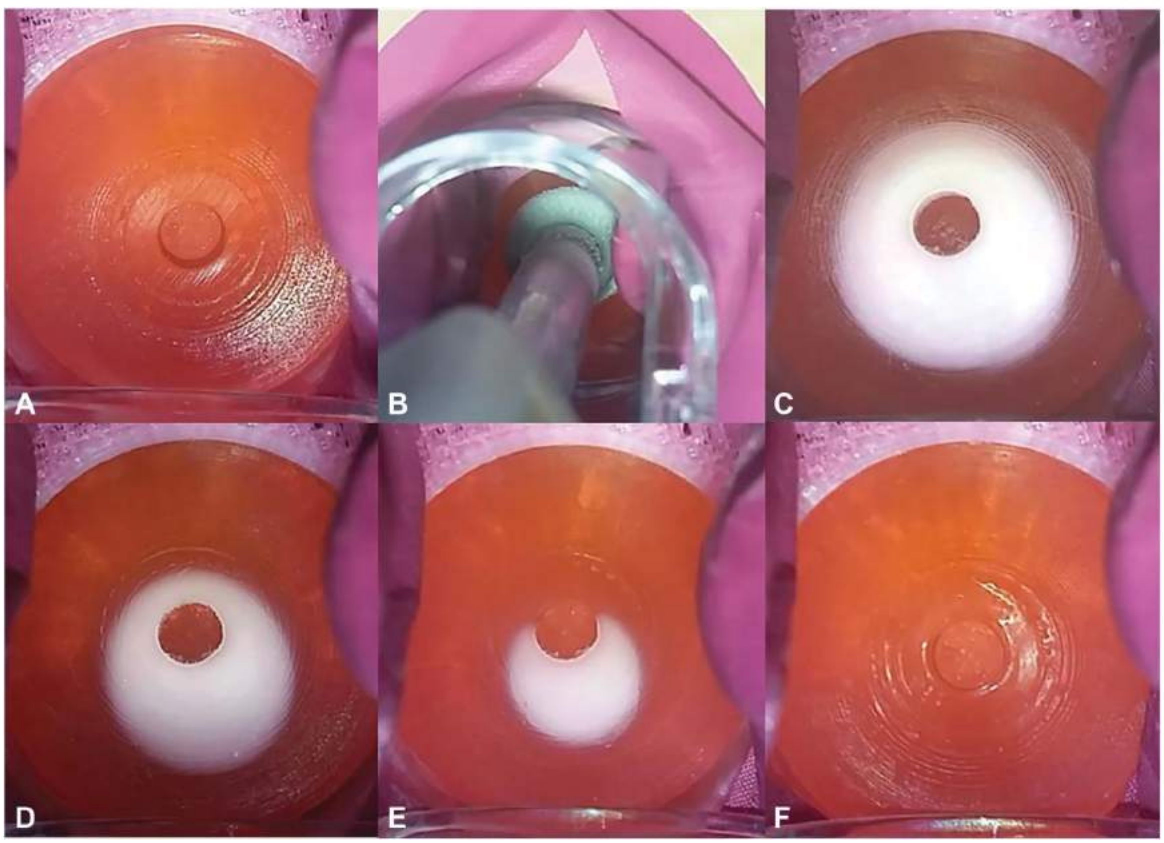

Fig. 7. Images of cervical gel model inside LUCIA before (**A**), during (**B**), and after (**C–F**) cryotherapy training. One minute after (**C**), 4 minutes after (**D**), 7 minutes after (**E**), and 10 minutes after (**F**).

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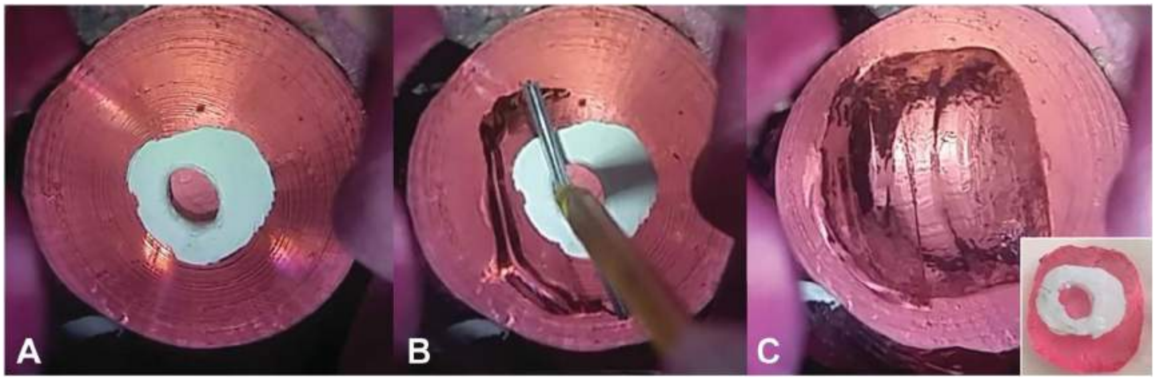

Fig. 8. Images of cervical gel model inside LUCIA before (**A**), during (**B**), and after (**C**) loop electrosurgical excision procedure (LEEP) training. Inset image shows LEEP sample that was removed.

Parra. Low-Cost Cervical Cancer Training Apparatus. Obstet Gynecol 2019.

LUCIA includes 20 three-dimensional printed cervical models (printed using polylactic acid) painted to depict the visible differences between a normal cervix, benign findings such as Nabothian cysts, cervical precancerous lesions including acetowhite changes, high-grade cervical precancer with abnormal vasculature, and findings consistent with invasive cervical cancer (Fig. 2). These models are used to practice identifying abnormal findings as well as provide hands-on training. LUCIA also comes with six molds used to make cervical models from ballistics gel (see Appendix 2, available online at http://links.lww.com/AOG/B274, for instructions to make gel models). All cervical models are designed to anatomic scale (3-cm diameter, 2–2.5-cm length), and to be interactive to train the user to perform a variety of skills.

The three-dimensional printed cervical models are used to train visual inspection with acetic acid and colposcopy (Figs. 3 and 4). Precancerous cervical models are painted with thermochromic paint that changes color from pink to white when exposed to temperatures above 88°F. This allows "white lesions" to appear after the application of hot water to simulate a positive visual inspection with acetic acid or colposcopy result when acetic acid is applied. The high-grade precancer and cancer models have vasculature painted on them using red paint, which absorbs green light, causing the vessels to appear dark when using the green filter feature of a colposcope.

Two normal and precancerous cervical models are printed using NinjaFlex material and are designed with a penetrable endocervical canal. These models are used to train providers to perform Pap and HPV sample collection and endocervical curettage (ECC; Fig. 5). During use, the models are moistened and corn flour is used to cover the outside surface and line the endocervical canal. The flour can then be removed using different cervical brushes and swabs to demonstrate adequate sample collection. Collected flour is visible on the tip of the brush or curette when extracted.

The gel cervical models are one-time use models used to teach cervical biopsy, cryotherapy, and LEEP. The biopsy gel models are made with four black beads (600 micrometers) lining the edge of the "squamocolumnar junction." The beads serve as targets to be removed using biopsy forceps, simulating cervical biopsy extraction (Fig. 6). For cryotherapy training, a cryogun can be used to treat the outer surface of the gel cervical model. The model becomes white when frozen and returns to its pink color over time, similar to a human cervix during and after cryotherapy (Fig. 7). For LEEP training, a standard LEEP machine can be used to remove a large sample from the gel cervical model. A "white lesion," painted on the center of the model using liquid paper, acts as a target that trainees must remove while performing a LEEP (Fig. 8).

The cost of LUCIA is $47 and includes the pelvic frame, vaginal canal, both cervical model holders, the three-dimensional printed cervical models, and six cervical gel molds (Appendix 3, available online at http://links.lww.com/AOG/B274).

For skills training, an assembled LUCIA model is placed on the edge of a table and the trainee sits facing the labial opening. The appropriate cervical model is placed in a holder and is visible when looking through the vaginal canal with a speculum.

Practice of each skill begins with the trainee separating the labia and inserting a speculum. An external light is used to better visualize the cervix,

Video 1. Low-cost Universal Cervical cancer Instructional Apparatus (LUCIA) demonstration video. A live demonstration of how to use the LUCIA model for cervical cancer prevention training. Video created by Sonia Parra. Used with permission.

such as a head lamp or book lamp adhered to the pelvic frame. Once the speculum is in place, the trainee can then practice performing Pap and HPV sample collection, visual inspection with acetic acid, colposcopy, cervical biopsy, ECC, cryotherapy, or LEEP on the cervical model. Once complete, the cervical model in the holder can be switched out to practice another skill. Video 1, available online at http://links.lww.com/AOG/B275, shows these skills being performed using LUCIA.

EXPERIENCE

LUCIA was evaluated as a teaching aid in cervical cancer training courses organized by the Project ECHO team from the University of Texas MD Anderson Cancer Center. Project ECHO is a telementoring program linking expert physicians with primary care clinicians in medically underserved areas through regular video conferences.[8] MD Anderson complements Project ECHO with locally held courses to increase the capacity of local medical providers for cervical cancer screening, diagnosis, and treatment.

In 2017 and 2018, six training courses were held using LUCIA in El Salvador (n=1); South Texas along the Mexico border (n=2), Sherman, Texas (n=1); and Mozambique (n=2). Institutional Review Board approval to evaluate the models was obtained from MD Anderson and Rice University (Protocol PA17-0562). Anonymous standardized provider evaluations were administered at three courses (Appendix 4, available online at http://links.lww.com/AOG/B274) and completed by 70 participants (36 in El Salvador; 18 in Sherman, Texas; and 16 in Beira, Mozambique). Results are summarized in Table 2 and qualitative feedback is summarized in Appendix 5, available online at http://links.lww.com/AOG/B274. LUCIA received a median score of 4 out of 5 for usefulness, skill improvement, and skill evaluation, and a median score of 5 out of 5 for likelihood to recommend the model and learning value.

The evaluation also asked participants to compare LUCIA with Jhpiego flashcards and an animal tissue model (beef tongue, Appendix 6 available online at http://links.lww.com/AOG/B274) for cervical cancer skills training. Over the three courses, 52 of 70 (74%) respondents preferred LUCIA over Jhpiego flashcards for visual inspection with acetic acid training. Cryotherapy was evaluated only during the course held in El Salvador, where 25 of 36 (69%) respondents preferred LUCIA over the animal tissue model for cryotherapy training. However, only 47% and 41% of respondents preferred LUCIA over the animal tissue model for biopsy and LEEP training, respectively. The main criticism was that the gel models felt too soft and did not cut like real cervical tissue. To overcome this, we increased the gel concentration for biopsy models from 30% to 35% gel wt/vol concentration and the LEEP models from 10% to 15% gel wt/vol concentration for our last course in Beira, Mozambique. We also kept the models refrigerated until immediately before use. A majority of participants in Beira preferred LUCIA for all skills evaluated (14/16 for visual inspection with acetic acid training, 9/16 for biopsy training, 9/16 for LEEP training).

DISCUSSION

In 2018, the Director-General of the World Health Organization made a global call to action to eliminate cervical cancer, which included improving access to early-stage diagnosis and treatment.[9] Improved access includes increasing the number of medical providers trained in the skills of early cervical cancer screening and prevention. LUCIA is a portable, low-cost simulation model that can be used to provide hands-on, comprehensive training for cervical cancer screening, diagnosis, and early treatment techniques in low-resource areas in the United States and globally,

Scan this image to view Video 1 on your smartphone.

Table 2. Summary of Cervical Cancer Training Courses by City

	McAllen, Texas	Laredo, Texas	Maputo, Mozambique	San Salvador, El Salvador	Sherman, Texas	Beira, Mozambique	Total
Date of course	February 11, 2017	September 9, 2017	November 14, 2017	December 12–14, 2017	March 3, 2018	April 25, 2018	February 2017–April 2018
No. of participants (no. who filled out the survey)	37	19	26	60 (36)	18 (18)	22 (16)	162 (70)
Skills trained using LUCIA	VIA, colposcopy, biopsy	VIA, colposcopy, biopsy, LEEP	VIA, colposcopy, biopsy	VIA, colposcopy, biopsy, cryotherapy, LEEP	VIA, colposcopy, biopsy, LEEP	VIA, Pap and HPV collection, ECC, colposcopy, biopsy, LEEP	VIA, Pap and HPV collection, ECC, colposcopy, biopsy, cryotherapy, LEEP
Q1: rate the usefulness of the model (1: worst imaginable–5: best imaginable)	—	—	—	4.11±0.40	4.19±0.46	4.07±0.26	4.12±0.39
Q2: likely to recommend the model to my colleagues (1: strongly disagree–5: strongly agree)	—	—	—	4.61±0.55	4.44±0.51	4.40±0.51	4.52±0.53
Q3: I improved my skills to screen for cervical cancer using the model (1: strongly disagree–5: strongly agree)	—	—	—	4.50±0.61	4.39±0.50	4.47±0.52	4.46±0.56
Q4: easy to self-evaluate my ability to perform skills using the model (1: strongly disagree–5: strongly agree)	—	—	—	4.61±0.49	4.33±0.49	4.13±0.52	4.43±0.53
Q5: the model added significant learning value to the course (1: strongly disagree–5: strongly agree)	—	—	—	4.69±0.47	4.44±0.51	4.47±0.52	4.58±0.50

VIA, visual inspection with acetic acid; LEEP, loop electrosurgical excision procedure; HPV, human papillomavirus; ECC, endocervical curettage.
Data are mean±SD unless otherwise specified.

where cervical cancer remains a common cancer in women.

In comparison with other models used for hands-on cervical cancer training, LUCIA can train providers on more skills at lower cost. The adaptability to simulate a variety of different skills makes LUCIA an excellent tool to increase local capacity to screen, diagnose, and treat precancerous cervical lesions based on local standards. For example, in rural areas of Latin America and Africa, clinicians and patients have limited access to medical facilities and equipment and therefore often rely on a "screen-and-treat" approach for cervical cancer prevention using visual inspection with acetic acid followed by cryotherapy of visible lesions.[10] To better implement "screen-and-treat" methods in rural areas, educators could use LUCIA to teach rural clinicians how to perform visual inspection with acetic acid and cryotherapy. However, in a hospital setting with reliable access to electricity and equipment, local educators may use LUCIA to train clinicians in colposcopy and LEEP.

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PEER REVIEW HISTORY

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