

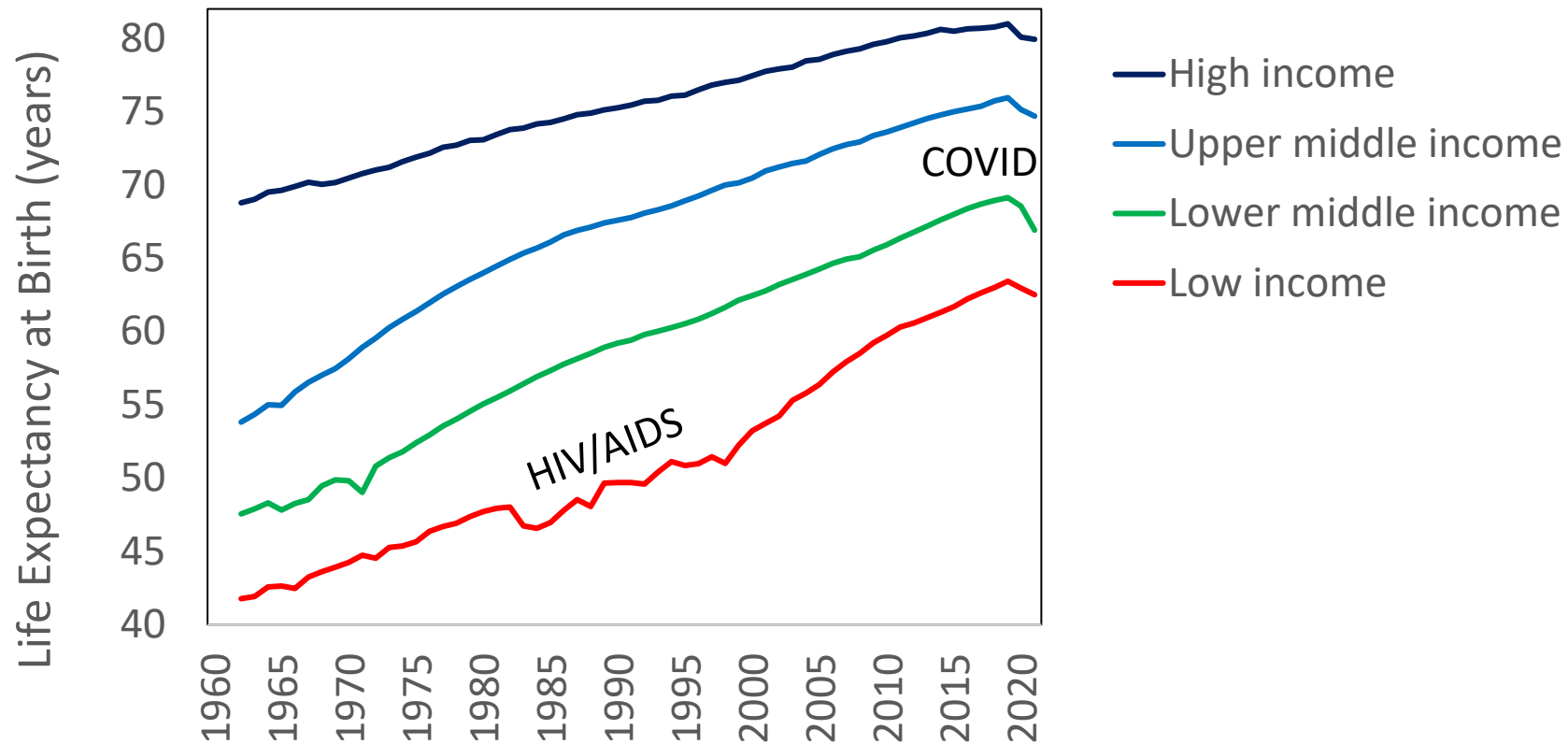
Systems Engineering to Improve Early Cancer Detection and Prevention in Low-Resource Settings

Rebecca Richards-Kortum

Department of Bioengineering
Rice360: Institute for Global Health Technologies
Rice University, Houston, TX

Global: Life Expectancy is Rising

Inequities are Shrinking (Slowly, For Now)

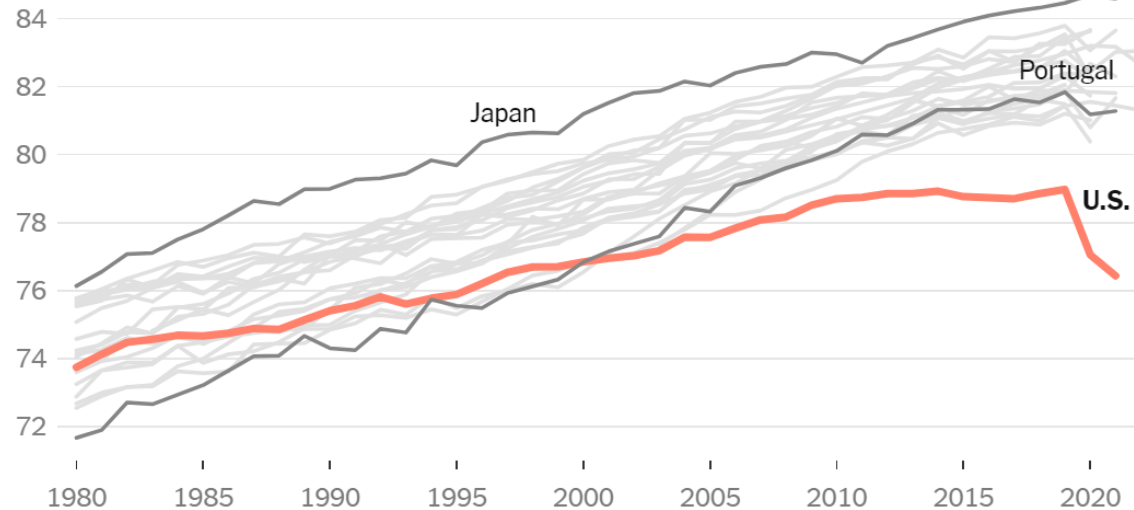


- Cancer is the **first** or **second** leading cause of premature death in **134** of **183** countries.
- Global cancer incidence will **increase by 50%** from 2018 to 2040.
- Number of cancer cases in countries with **low Human Development Index** will **double**.

US: Life Expectancy is Falling Inequities are Increasing

Life expectancy in the United States falls behind other rich countries

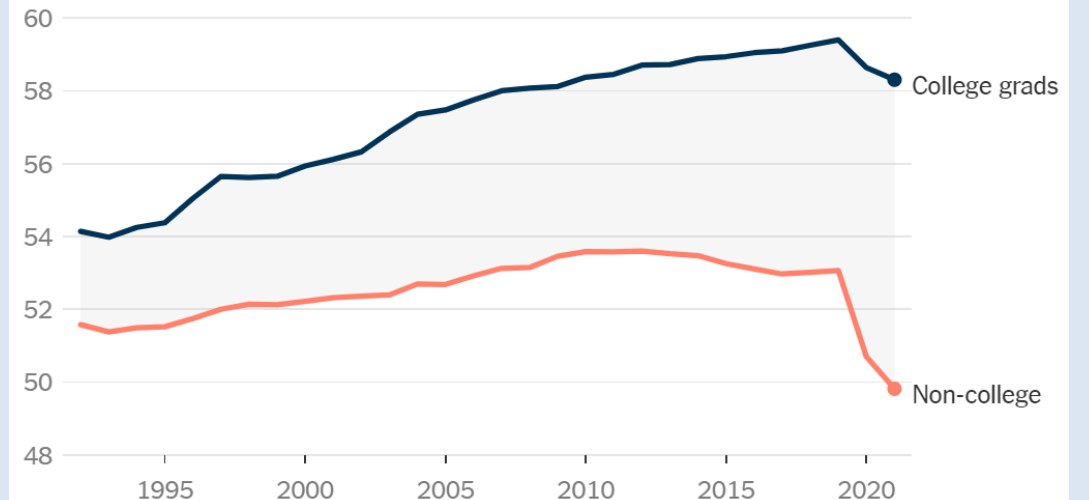
Life expectancy at birth



Source: Anne Case and Angus Deaton, Princeton University • By The New York Times

The mortality gap between Americans with and without four-year degrees is widening

Average years of life remaining for 25-year-old Americans



Source: Anne Case and Angus Deaton, Princeton University • By The New York Times

Cancer is the **second leading cause of death** in the US.

Racial and ethnic minorities and medically underserved populations share a **disproportionate cancer burden**.

Early Detection (& Rx) Saves Lives!

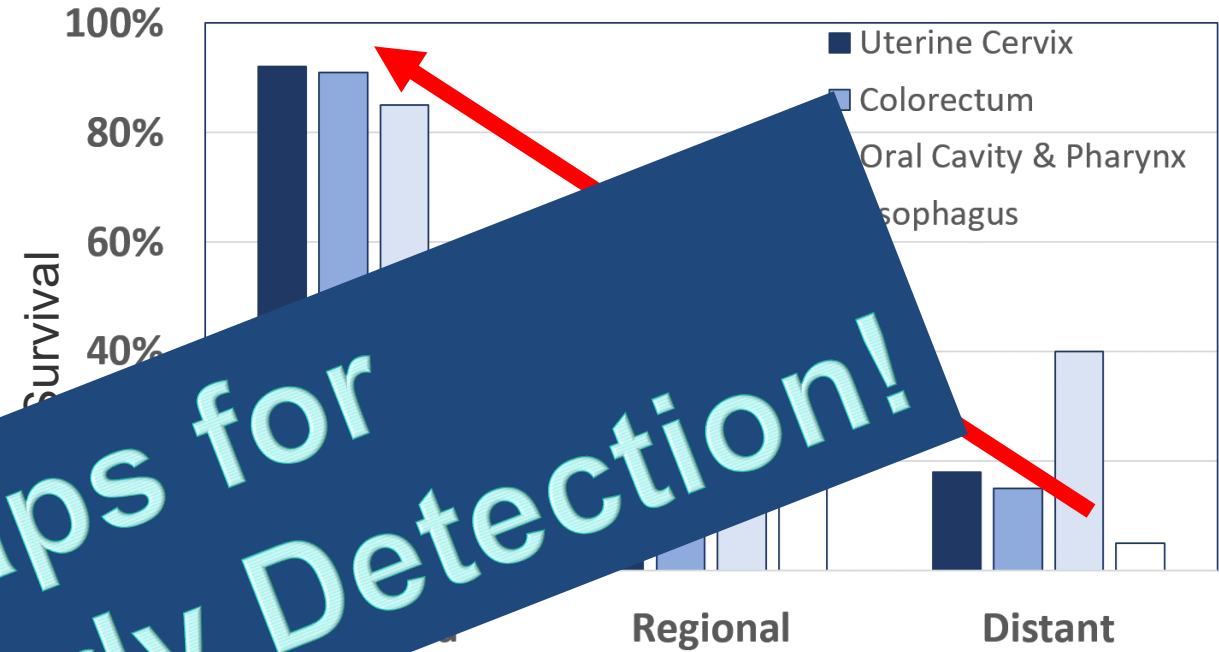
- Epithelial cancers can be prevented or cured by detecting and treating **pre-cancerous lesions** and early-stage disease.

Early Detection Missed

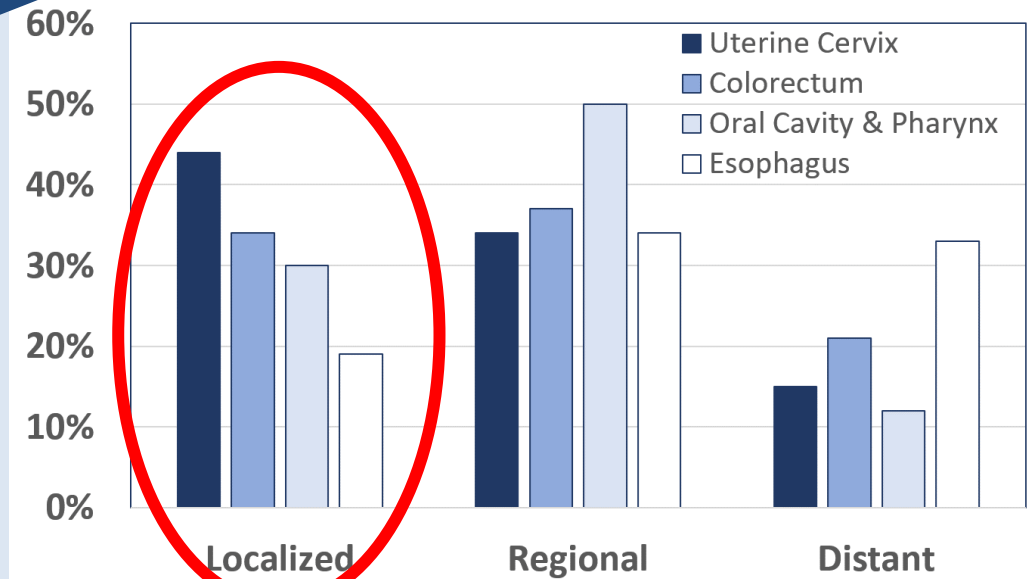
- Less than 10% of epithelial cancers are detected at localized stage, compared to 10-15% for early detection.
- Individuals with higher socioeconomic status have greater access to early detection

Major Gaps for
Screening & Early Detection!

Five Year Survival vs. Stage at Diagnosis



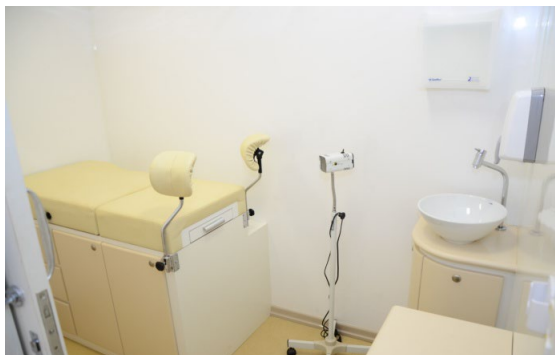
Stage Distribution at Diagnosis



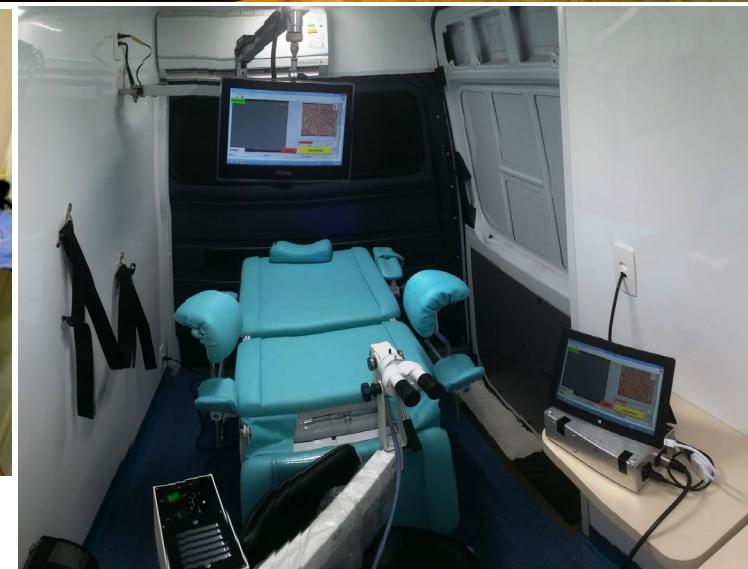


Blood collection

Pap smear collection



Surgical center



Diagnosis and Treatment



Mammogram Screening

An annual mammogram offers peace of mind. Take the time to schedule yours today.



Insured or Uninsured

Regardless of a woman's ability to pay, we are providing access to screening, diagnostics, and treatment services.



Mobile Mammography

Our 3D Mobile Mammography program services women from Matagorda to Shelby Counties.



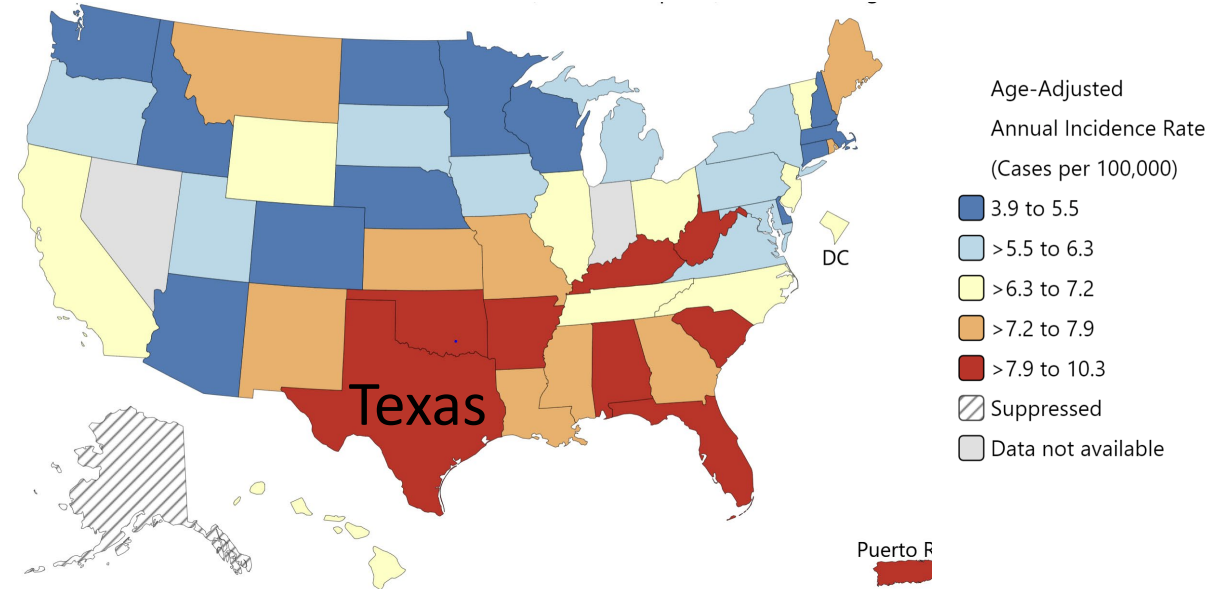
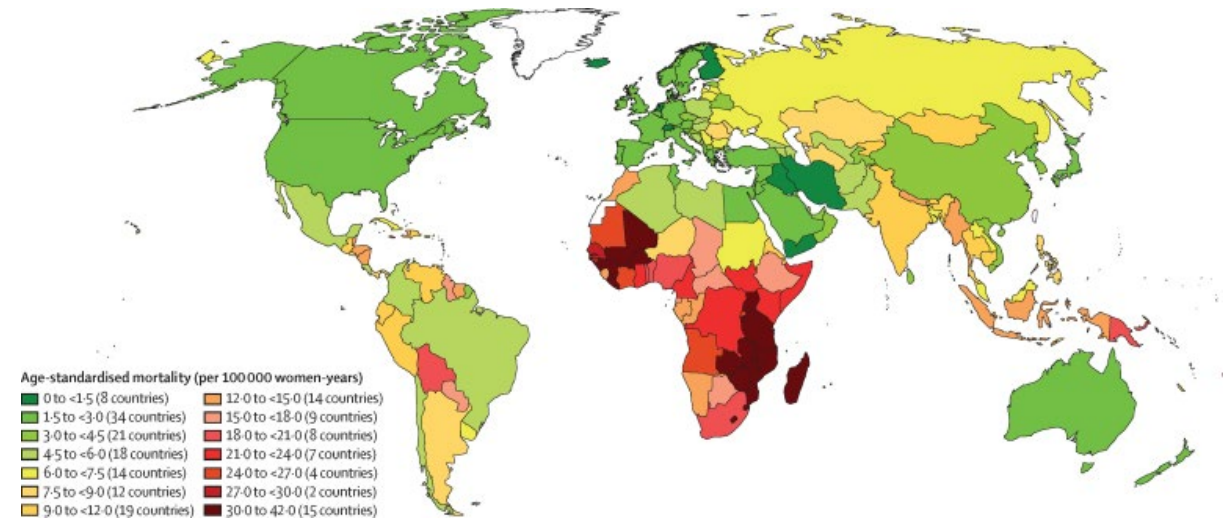
3D Technology for all patients

We now offer 3D mammography at our centers and on our mobile coaches.



Cervical Cancer is Preventable. Prevention Strategies are Failing!

Global Cervical Cancer Mortality



4th

most common cancer
in women worldwide

>85%

of deaths
occur in LMICs

3rd

highest cervical
cancer rate in US

Worst 10

HPV vaccination &
screening rates

Why Systems Approach?



Treatment:
Invasive Cancer
Pre-Invasive Disease

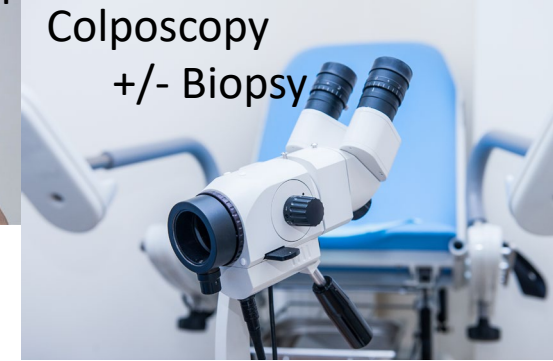
(Early) Diagnosis

Screening

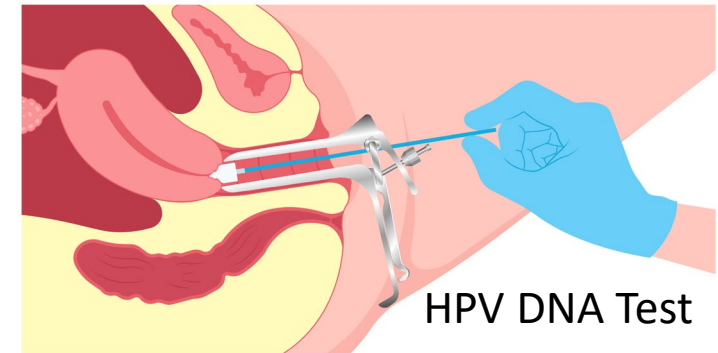
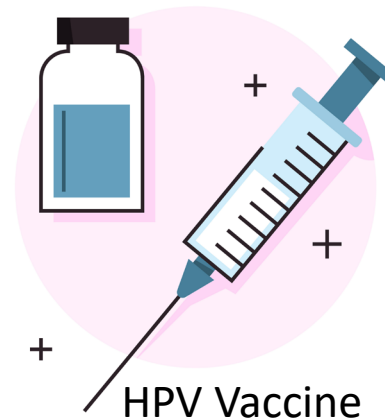
Prevention



Thermal
Ablation



Colposcopy
+/- Biopsy

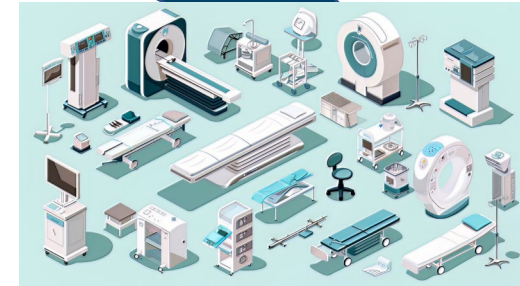


Why Systems Approach?

Health Facilities
Laboratories
BMET Workshops

Government

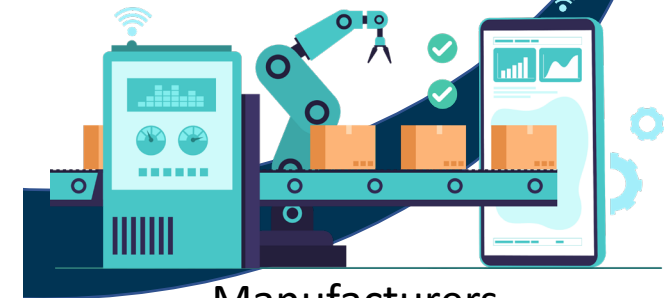
Equipment Dealers
Regulatory Agencies
Manufacturers
Researchers



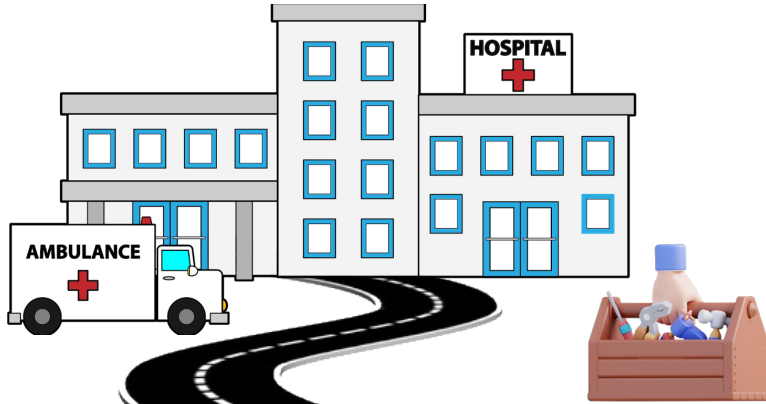
Equipment Dealers



Researchers



Manufacturers



2018

WHO Director-General calls for all countries to take action to help end the suffering caused by cervical cancer



Woman being screened for cervical cancer in a rural clinic, Kenya

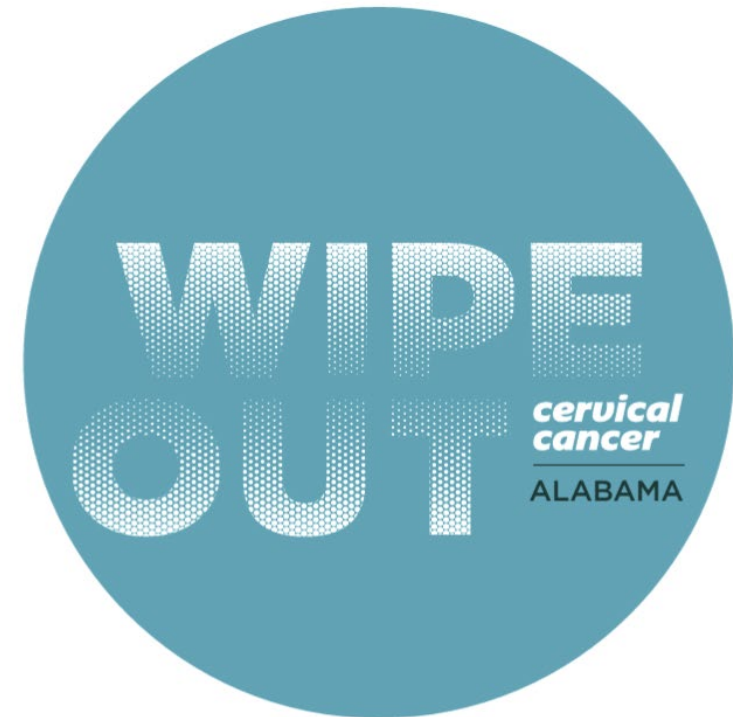
90%
Girls
vaccinated

70%
Women
screened

90%
Women
treated

STRATEGIC ACTION PLAN FOR CERVICAL CANCER ELIMINATION AS A PUBLIC HEALTH PROBLEM IN THE STATE OF ALABAMA

2023-2033



Training Models: Cervical Cancer Prevention



1,978 views | Mar 4, 2019, 10:07am

Student-Designed Cervical Cancer Models Are Helping With Cervical Cancer Training In Malawi



Christine Ro Contributor @

Science

I write about science and international development (broadly defined).

TWEET THIS



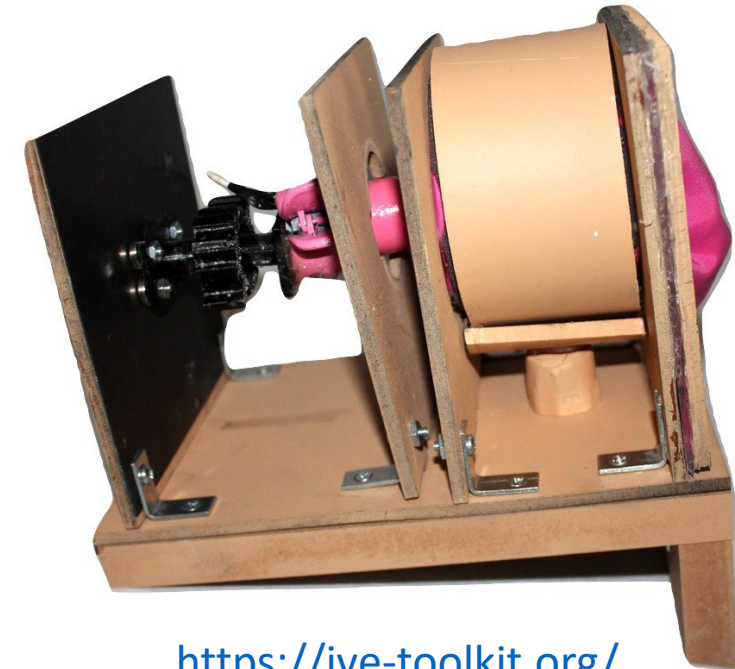
"It was a big shock," Mia says, to realize that Malawi has one of the world's highest rates of cervical cancer.



To practice cervical cancer biopsies, medical students might use models with raw meat. Yes, meat, such as beef tongue. This is messy and easily contaminated, and it's especially impractical for warm and remote settings like some Malawian towns.



A group of students from the Malawi Polytechnic and Rice University has designed gel-based models of the cervix that are substantially cheaper, more portable, and frankly more palatable than plastic/meat models. The pelvic frame is made of wood, while the vaginal canal is made of PVC pipe, fabric and foam. Sonia Gomez Parra, a Ph.D. researcher who mentored the students designing these new models, explains, "Each model comes with a pelvis, cervical



<https://ive-toolkit.org/>

Transforming Engineering Education in African Universities to Solve Local and Global Challenges



Project ECHO Programs at MD Anderson

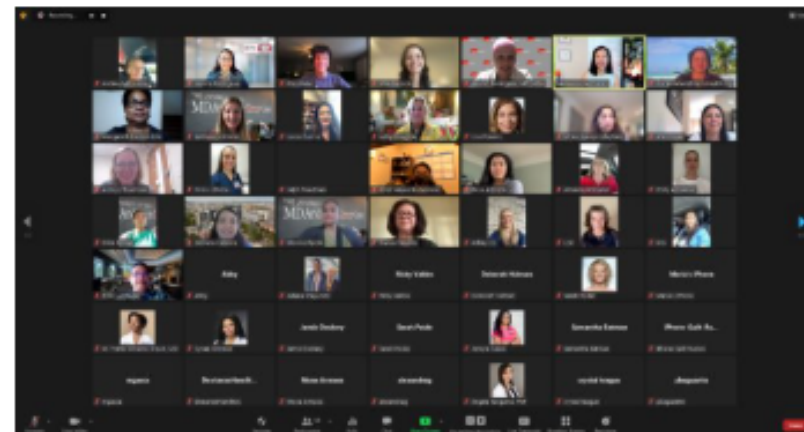


The map above showcases MD Anderson's Project ECHO's coverage globally. (Click to enlarge.)

Since 2014

MD Anderson's programs have held:

1,176 ECHO telementoring sessions to expand knowledge and skills and to support **3,534** participants in **27** countries.



Project ECHO is being used to elevate evidence-based cancer prevention and control activities, as well as engage providers in learning across the continuum of cancer care worldwide. The ECHO model is part of a larger comprehensive strategy to build capacity in partnering region.

Programs

Program for Reducing Cervical Cancer in Texas

Program for Reducing Cervical Cancer in Mozambique

Science Translational Medicine

BIOENGINEERING

An integrated isothermal nucleic acid amplification test to detect HPV16 and HPV18 DNA in resource-limited settings

Kathryn A. Kundrod^{1,2*}, Maria Barra^{1†}, Alexis Wilkinson^{1†}, Chelsey A. Smith¹, Mary E. Natoli¹, Megan M. Chang¹, Jackson B. Coole¹, Akshaya Santhanaraj¹, Cesaltina Lorenzoni³, Celda Mavume³, Hira Atif³, Jane Richards Montealegre^{4‡}, Michael E. Scheurer⁴, Philip E. Castle^{2,5}, Kathleen M. Schmeler⁶, Rebecca R. Richards-Kortum^{1*}

Six user steps

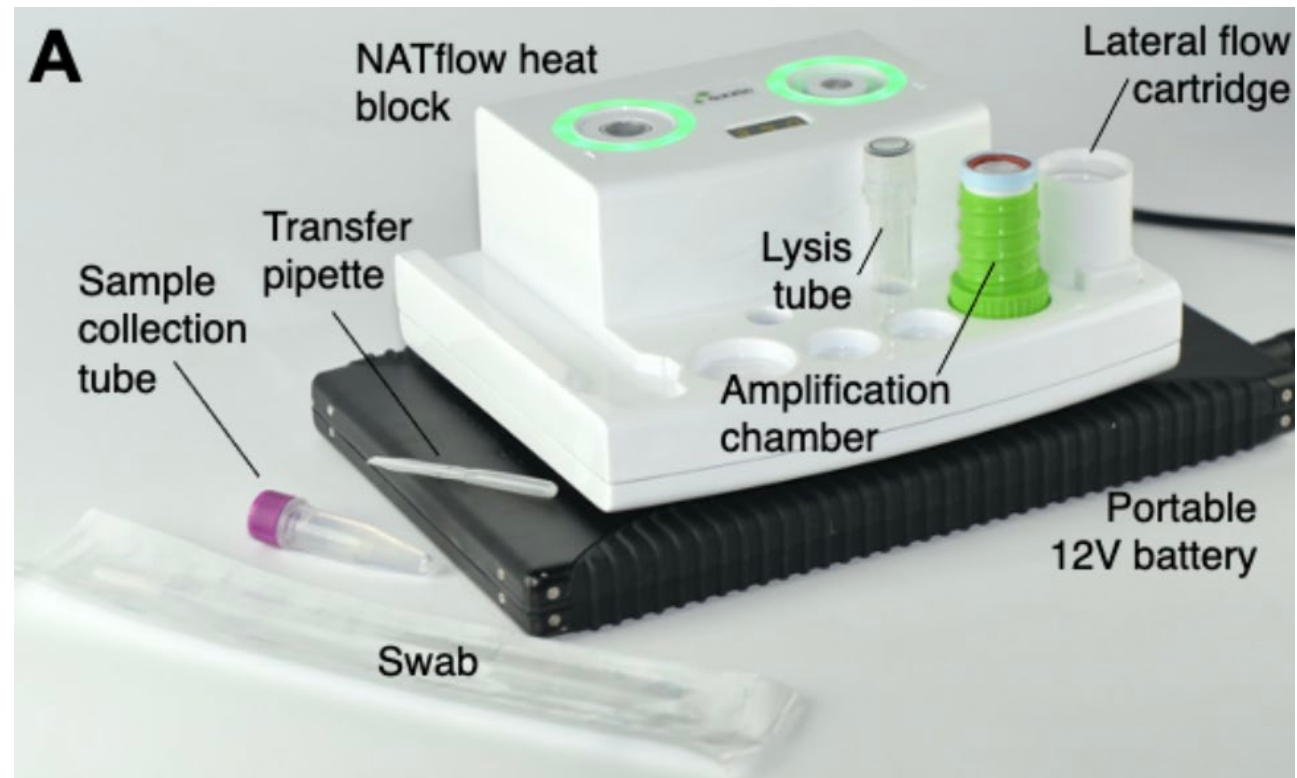
Sample to answer in 45 min

Projected per-test cost: <\$5

Projected instrumentation cost: <\$1000

**Clinically relevant limit of detection of
1,000 HPV16 / HPV18 DNA copies**

**Field-tested in Houston, TX
and Maputo, Mozambique**



Reimagining the Gynecological Exam

Introducing the Pocket Colposcope

FDA CLEARED

FDA
CLEARED



Research Article

Multicontrast Pocket Colposcopy Cervical Cancer Diagnostic Algorithm for Referral Populations

Erica Skerrett¹, Zichen Miao², Mercy N. Asiedu³, Megan Richards⁴, Brian Crouch¹, Guillermo Sapiro⁴, Qiang Qiu², and Nirmala Ramanujam¹

¹Department of Biomedical Engineering, Duke University, Durham, NC, USA

²Department of Electrical and Computer Engineering, Purdue University, West Lafayette, IN, USA

³Department of Computer Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA

⁴Department of Electrical and Computer Engineering, Department of Biomedical Engineering, Department of Computer Science, Department of Mathematics, Duke University, Durham, NC, USA

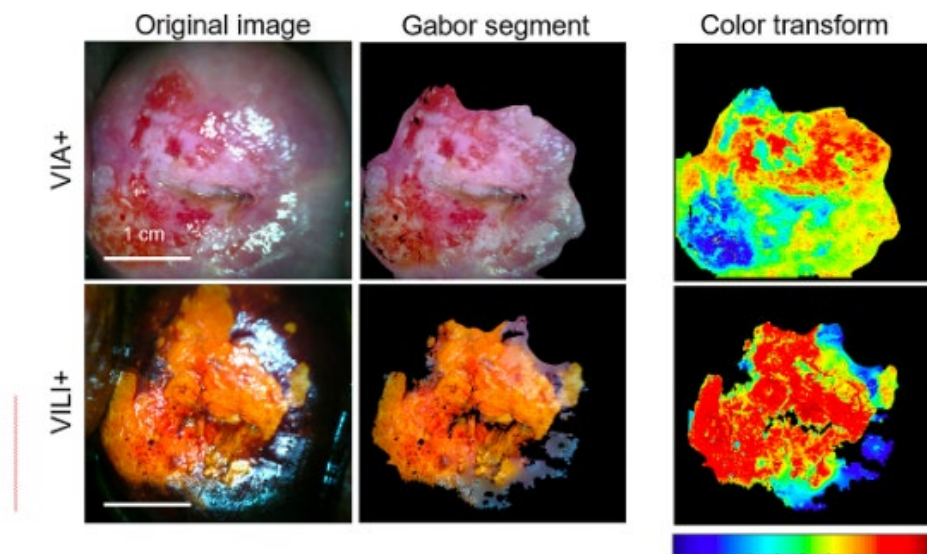
Correspondence should be addressed to Erica Skerrett; erica.skerrett@duke.edu

Erica Skerrett and Zichen Miao contributed equally to this work.

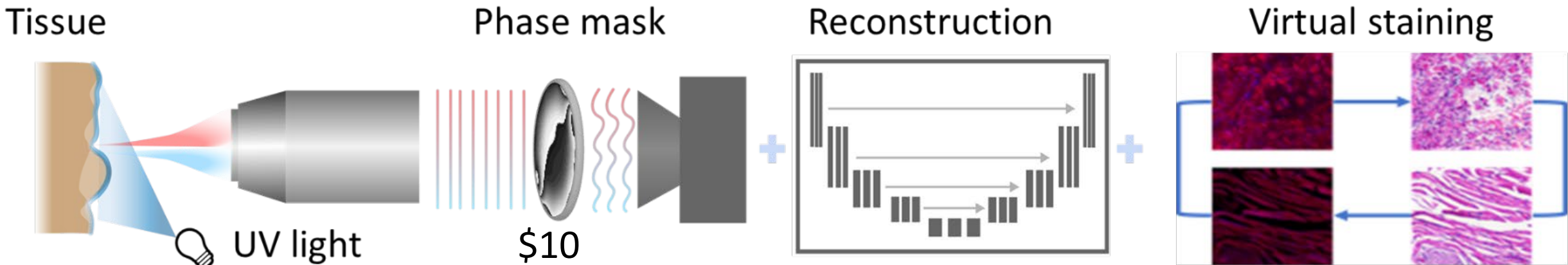
Received 26 March 2022; Accepted 19 July 2022; Published 1 September 2022

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Objective and Impact Statement. We use deep learning models to classify cervix images—collected with a low-cost, portable Pocket colposcope—with biopsy-confirmed high-grade precancer and cancer. We boost classification performance on a screened-positive population by using a class-balanced loss and incorporating green-light colposcopy image pairs, which come at no additional cost to the provider. **Introduction.** Because the majority of the 300,000 annual deaths due to cervical cancer occur in countries with low- or middle-Human Development Indices, an automated classification algorithm could overcome limitations caused by the low prevalence of trained professionals and diagnostic variability in provider visual interpretations. **Methods.** Our dataset consists of cervical images ($n = 1,760$) from 880 patient visits. After optimizing the network architecture and incorporating a weighted loss function, we explore two methods of incorporating green light image pairs into the network to boost the classification performance and sensitivity of our model on a test set. **Results.** We achieve an area under the receiver-operator characteristic curve, sensitivity, and specificity of 0.87, 75%, and 88%, respectively. The addition of the class-balanced loss and green light cervical contrast to a Resnet-18 backbone results in a 2.5 times improvement in sensitivity. **Conclusion.** Our methodology, which has already been tested on a prescreened population, can boost classification performance and, in the future, be coupled with Pap smear or HPV triaging, thereby broadening access to early detection of precursor lesions before they advance to cancer.



Point-of-Care Pathology



Total System Cost: ~\$5,000

nature communications

Article

<https://doi.org/10.1038/s41467-024-47065-2>

DeepDOF-SE: affordable deep-learning microscopy platform for slide-free histology

Received: 25 August 2023

Accepted: 19 March 2024

Published online: 05 April 2024

Lingbo Jin^{1,6}, Yubo Tang^{2,6}, Jackson B. Coole², Melody T. Tan², Xuan Zhao¹, Hawraa Badaoui³, Jacob T. Robinson¹, Michelle D. Williams⁴, Nadarajah Vigneswaran⁵, Ann M. Gillenwater³, Rebecca R. Richards-Kortum^{2,6} & Ashok Veeraraghavan¹

December 14, 2020 | 117 (52) 33051–33060 | <https://doi.org/10.1073/pnas.2013571117>

Deep learning extended depth-of-field microscope for fast and slide-free histology

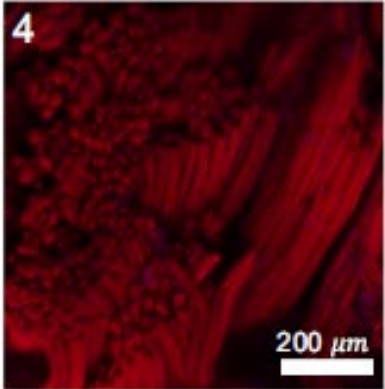
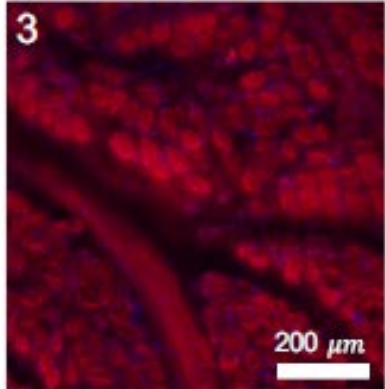
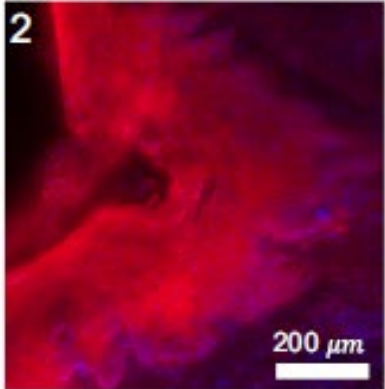
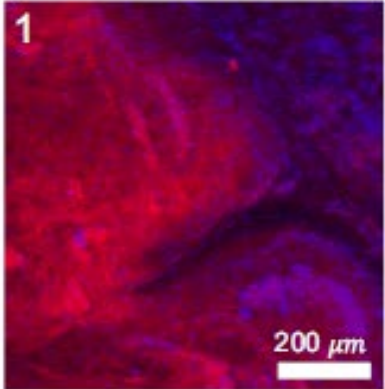
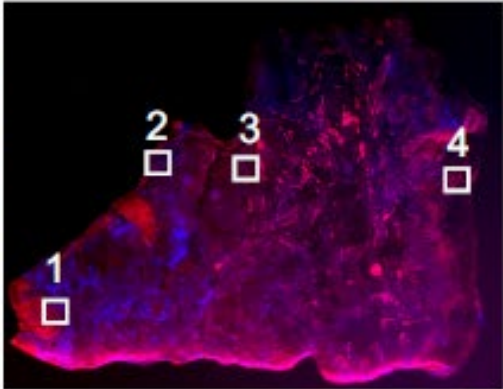
Lingbo Jin^{a,1}, Yubo Tang^{b,1}, Yicheng Wu^{a,c}, Jackson B. Coole^b, Melody T. Tan^b, Xuan Zhao^c, Hawraa Badaoui^d, Jacob T. Robinson^{a,b}, Michelle D. Williams^e, Ann M. Gillenwater^d, Rebecca R. Richards-Kortum^{b,2}, and Ashok Veeraraghavan^{a,2}

PNAS

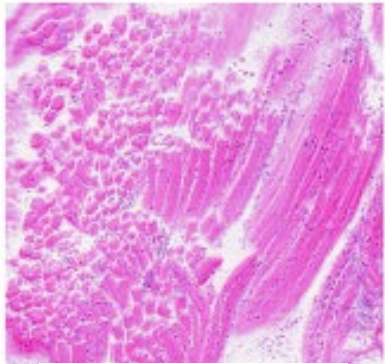
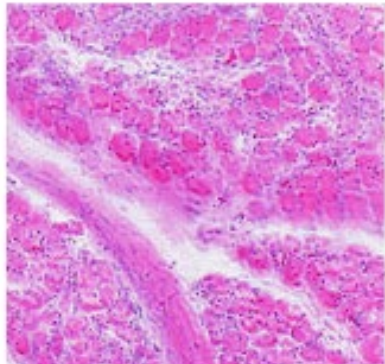
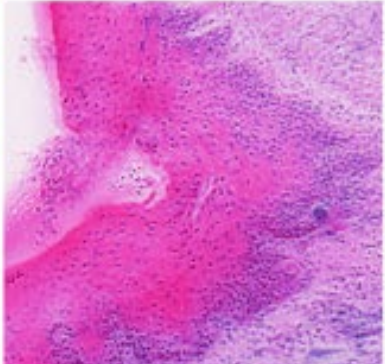
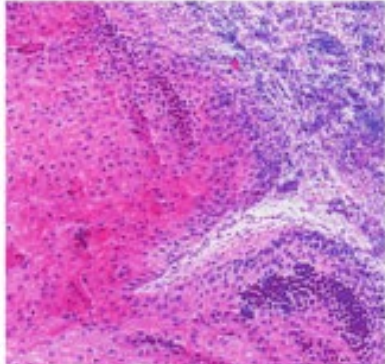
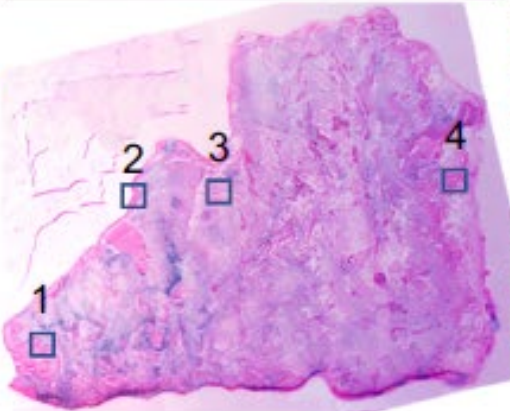
Proceedings of the National Academy of Sciences of the United States of America

Point-of-Care Pathology

DeepDOF-SE
fluorescence



DeepDOF-SE
GAN staining



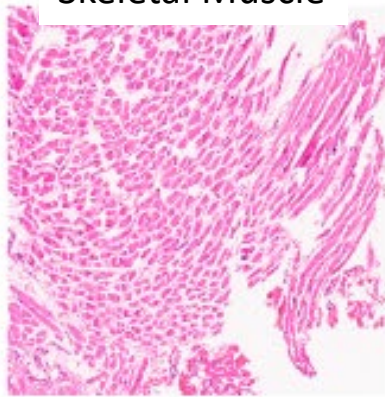
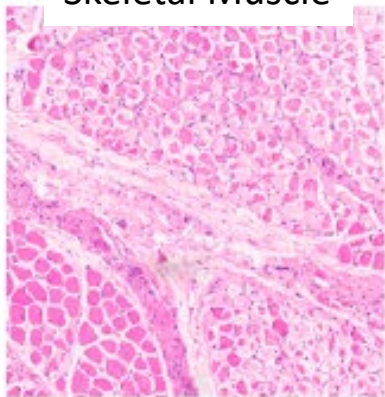
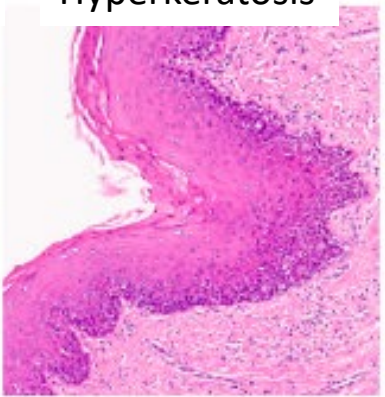
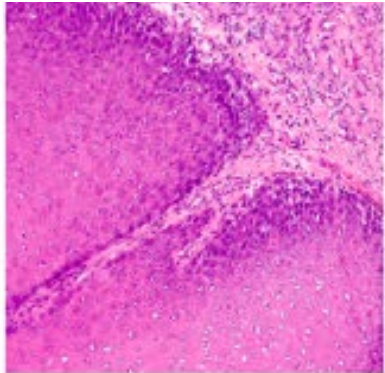
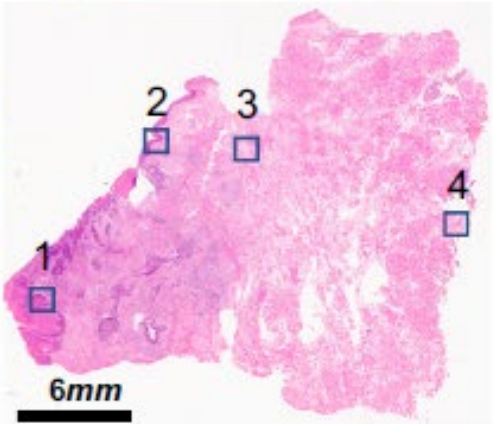
Hyperplasia/Dysplasia

Hyperkeratosis

Skeletal Muscle

Skeletal Muscle

Standard
FFPE H&E



Diagnostic Excellence in U.S. Rural Healthcare: A Call to Action



Why Systems Approach?

Obstacles to Diagnosis in Rural Settings:

- Limited access to advanced diagnostic tools
- Shortage of specialists
- Substantial social determinants of health affect patients

How To Advance Diagnosis In Rural Areas:

1. Enhance Specialty Care & Surgical Service Lines

- Deploy mobile care units for diagnostic testing
- Build community-based diagnostic hub & spoke model
- Invest in the right emerging technologies (e.g., AI-powered colonoscopy)

2. Strengthen Care Coordination

- Tele-health and tele-mentoring

3. Screen for Social Determinants of Health

- Health literacy for screening / modifiable risk factors



PATIENT
SAFETY

Call to Action

- **Early detection** can save lives & improve outcomes at lower cost
 - **Identify priority needs** for new technologies to improve early detection
 - **Global collaborations** can speed development and evaluation
- Make **technology development** a core component of **public health efforts to improve cancer prevention & early detection**
 - Integrate new technologies in **systems based solutions**
 - Develop strategies to ensure **uptake** in all settings
 - **Technology + Policy + Implementation Research**



Center for Innovation & Translation of Point of Care Technologies for Expanded Cancer Care Access

AFFORDABLE, EFFECTIVE, POINT-OF-CARE TECHNOLOGIES *for early cancer detection*

CITEC is a collaboration of engineers, oncologists, and international global health partners that will unite a global community of investigators to develop point-of-care technologies to detect and treat cancer.

We will identify needed technologies, accelerate their development, evaluate their performance and impact in diverse settings, and train local users and technology developers to create and disseminate more equitable technologies.



THE CENTER FOR INNOVATION AND
TRANSLATION OF POC TECHNOLOGIES
FOR EXPANDED CANCER CARE ACCESS



rice360@rice.edu

Our Partners:



THE UNIVERSITY OF TEXAS
**MD Anderson
Cancer Center**
Making Cancer History®



RICE360
Institute for Global Health Technologies



**Universidade de São Paulo
Brasil**



ha
HOSPITAL DE AMOR



POCTRN
POINT OF CARE TECHNOLOGIES
RESEARCH NETWORK

*Rice-led research center awarded \$6.5M
over 5 years for POC technologies*

POCTRN 
POINT-OF-CARE TECHNOLOGIES
RESEARCH NETWORK

nature reviews bioengineering 22 December 2023
**Optical imaging for screening and early cancer
diagnosis in low-resource settings**

[Rebecca Richards-Kortum](#) , [Cesaltina Lorenzoni](#), [Vanderlei S. Bagnato](#) & [Kathleen Schmeler](#)

Innovation Award Applications Due:
June 6, 2025

<https://www.poctrn.org/citec-solicitation-2025>

Rice University

- Dr. Yubo Tang
- Dr. Mary Jin
- Dr. Ashok Veeraraghavan
- Dr. Kathryn Kundrod
- Dr. Richard Schwarz
- Dr. Jenny Carns
- Huayu Hou

MD Anderson Cancer Center

- Dr. Kathleen Schmeler
- Dr. Mila Salcedo
- Dr. Ellen Baker
- Dr. Ann Gillenwater
- Dr. Michelle Williams

UEM, Mozambique

- Dr. Cesaltina Lorenzoni

Barretos Cancer Hospital

- Dr. Julio Possati

Acknowledgments



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R01DE032051

R01HL166413

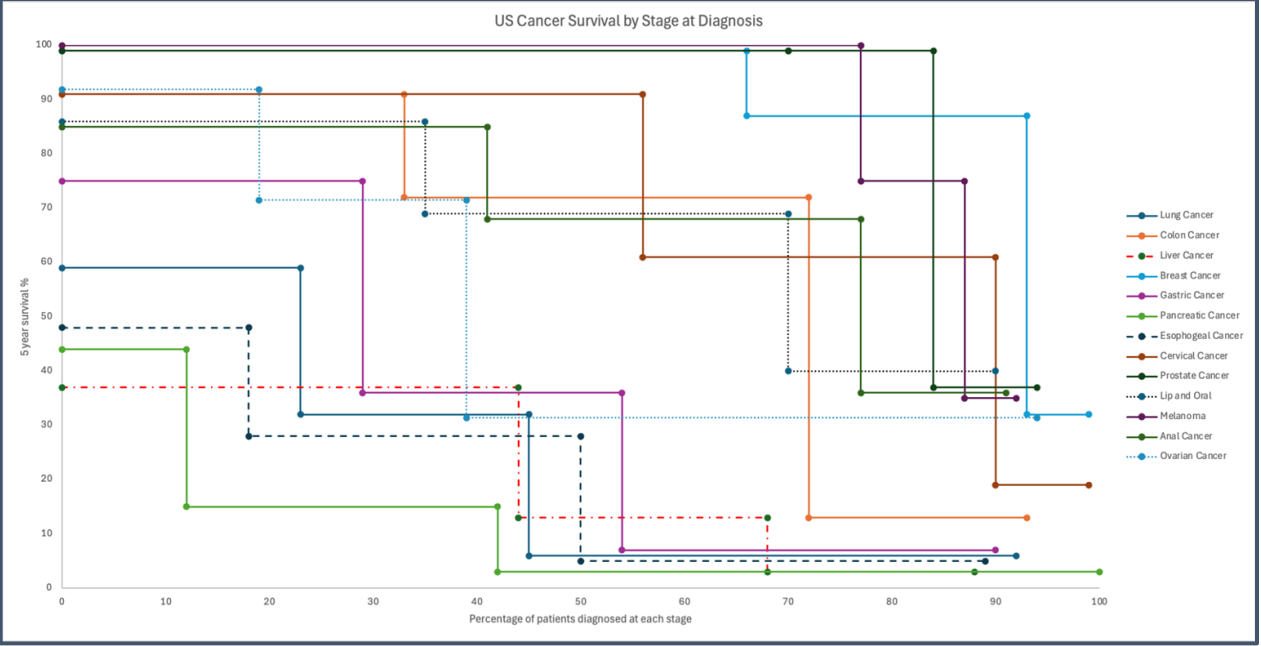
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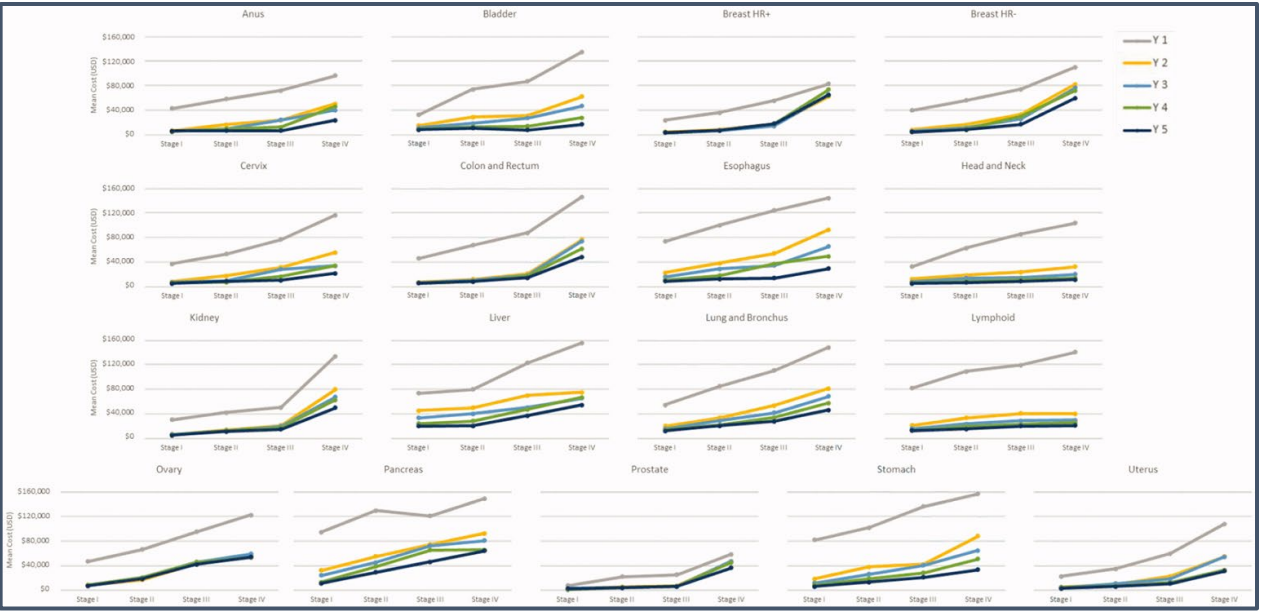
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U01CA292741
R01CA232890

D24AC00296





Above graph compiled by Casey Howard from SEER data



Scoring Factors

- US Stage at Diagnosis
- US 5-year Survival by Stage

Top 11

- US New Cases 2025
- US Death Rate

Top 8

- Avg US Cost in year 1 by stage Medicare beneficiaries

Priority Ranking

1. Lung
2. Pancreas
3. Liver
4. Colorectal
5. Stomach
5. Esophagus