Could AI Provide Global and Equitable Access to Medical Diagnostics?

Johan Lundin, MD, PhD

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and

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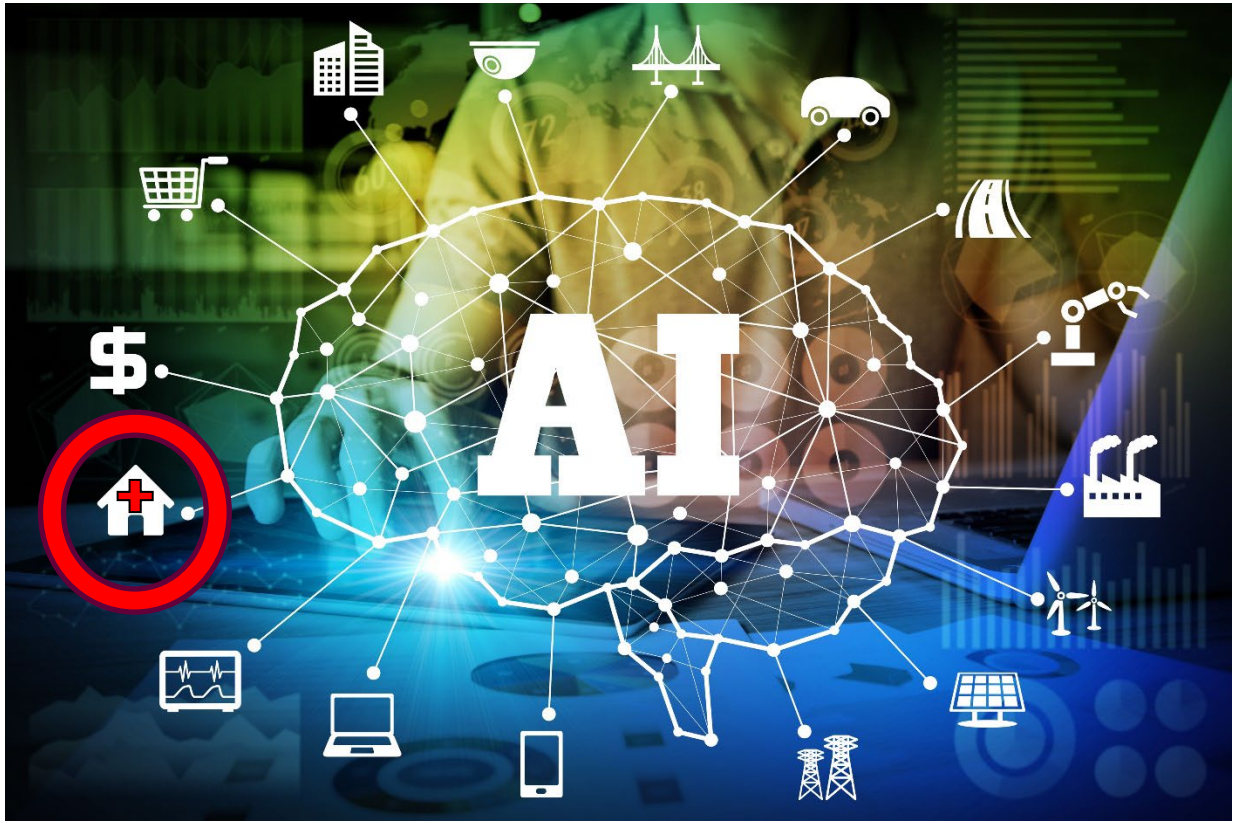
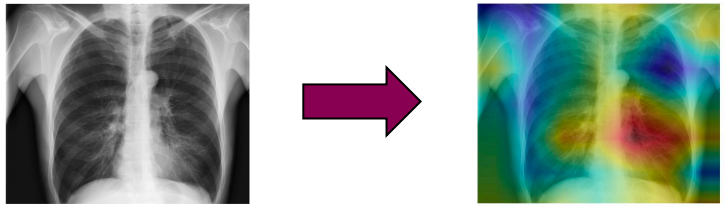

AI

Recent significant steps towards artificial general intelligence (AGI) concerns the whole society

E.g. large language models and generative AI

Significant progress within image-based AI

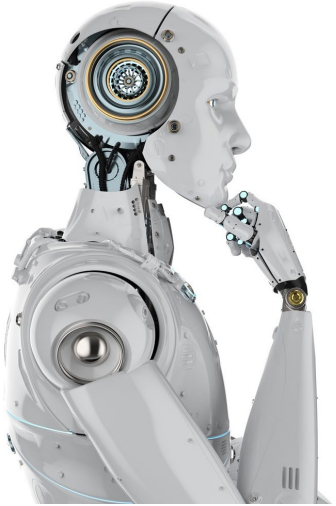


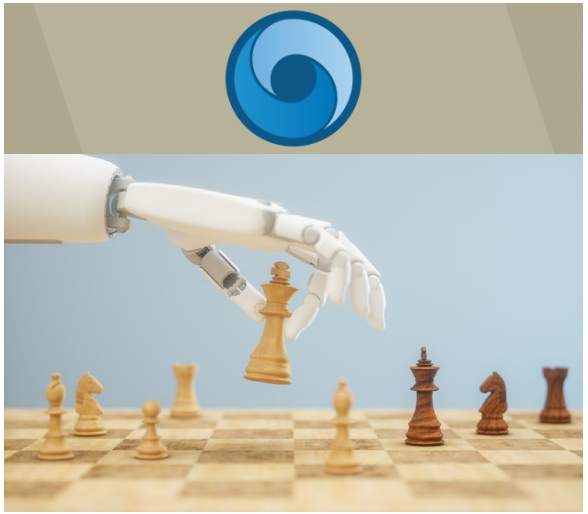
Three big promises of medical AI today

- Create virtual and personal expert assistants
- Go beyond current expert-based capabilities
- Improve access to diagnostics

Human chess world champion learns from games played by AI

Medical experts are likely to benefit from AI in a similar way



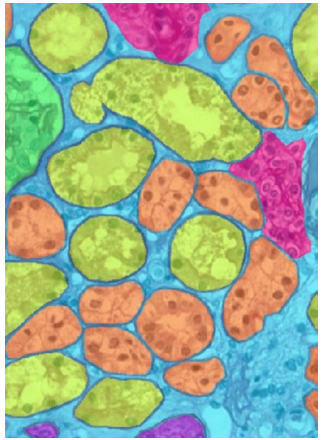


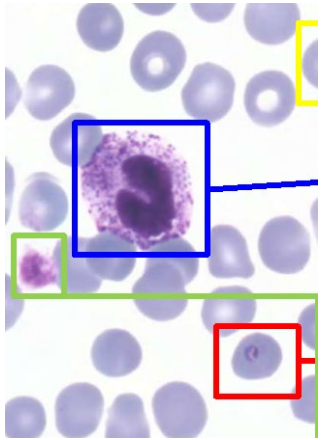
AlphaZero, self-taught AI-based world champion of chess*

Magnus Carlsen, the current human champion of chess

*Silver, D. et al. Science. 362, 1140 (2018).

AI will impact all medical fields where an expert makes a visual interpretation





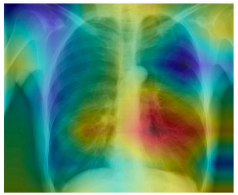
Pathology

Microbiology

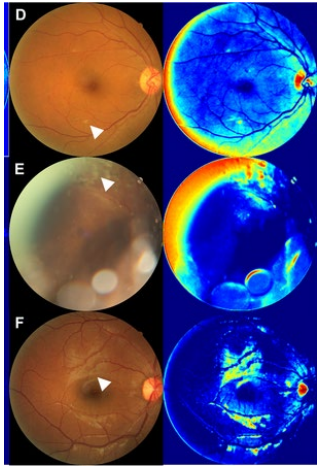
Input
Chest X-Ray Image

CheXNet
121-layer CNN

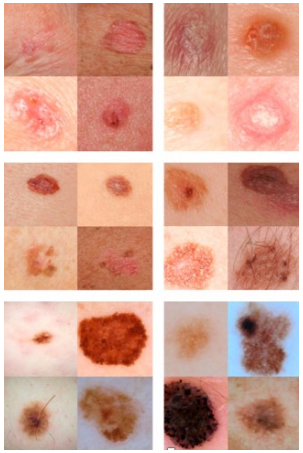
Output
Pneumonia Positive (85%)

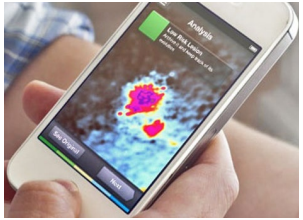


Radiology



Ophthalmology





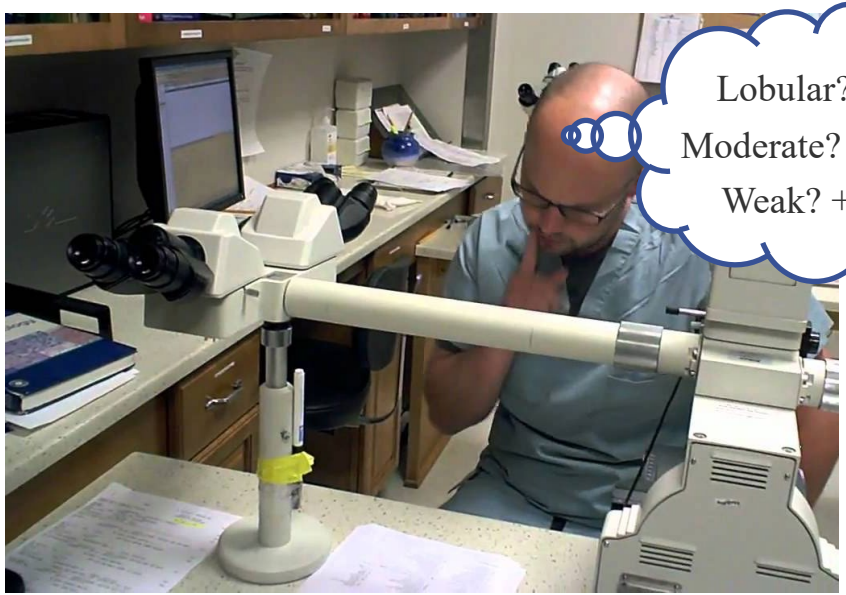
Dermatology

Johan Lundin **Crude estimate: >7-8 billion visual diagnostic assessments globally per year**

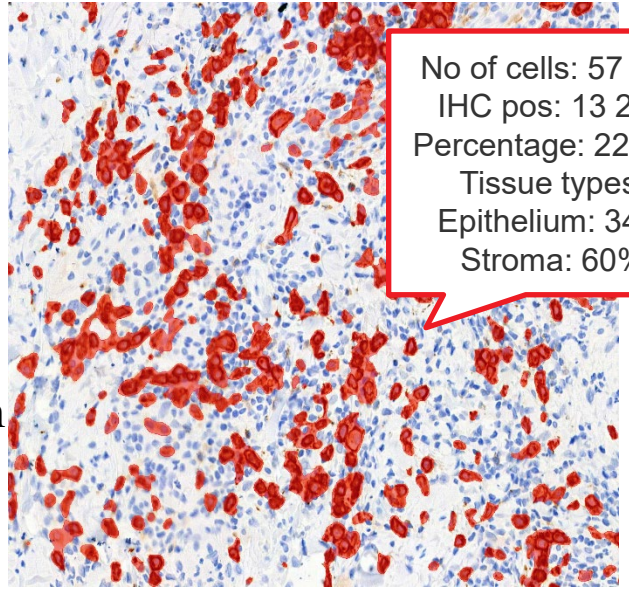
The transformation of pathology

Pathology transforming from analog and manual to digital and automated

Today pathologists give a subjective description, tomorrow it will be supported by AI



Digitization



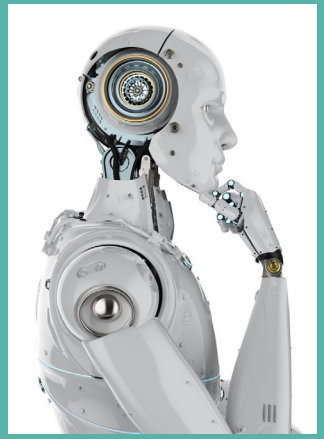
Descriptive microscopy

Quantitative microscopy

AI based on deep learning

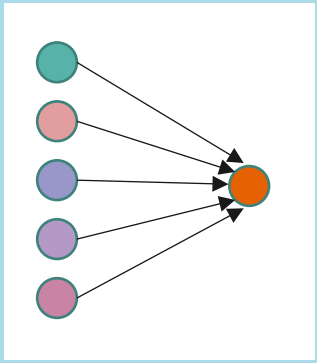
Artificial Intelligence

Engineering of machines and programs that mimic human intelligence



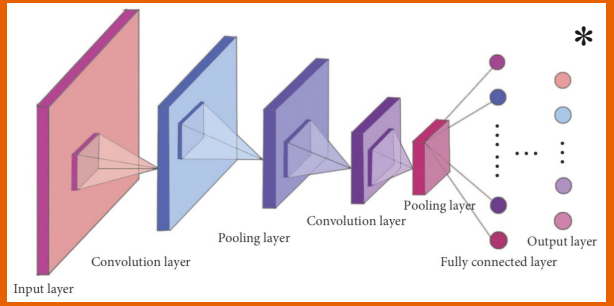
Machine Learning

Ability to learn without being explicitly programmed



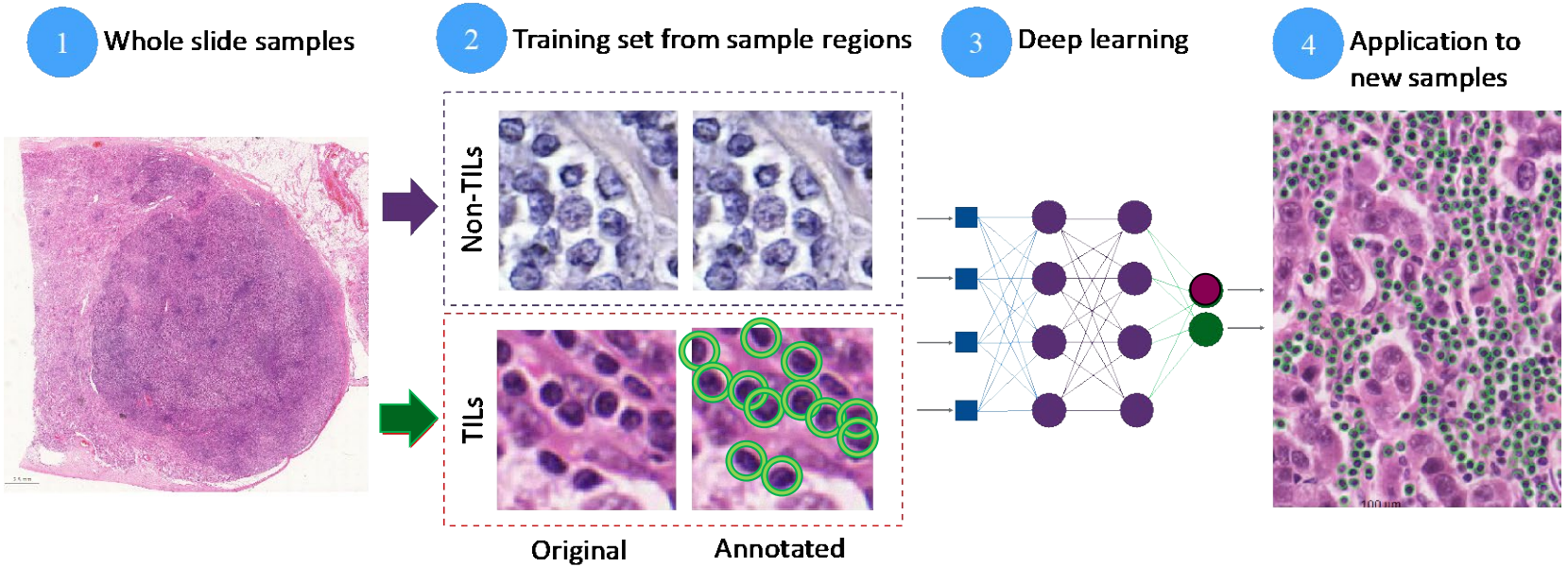
Deep Learning

Learning based on deep artificial neural networks



*Chen et al. Modelling and Simulation in Engineering. 2019;2019:8796743.

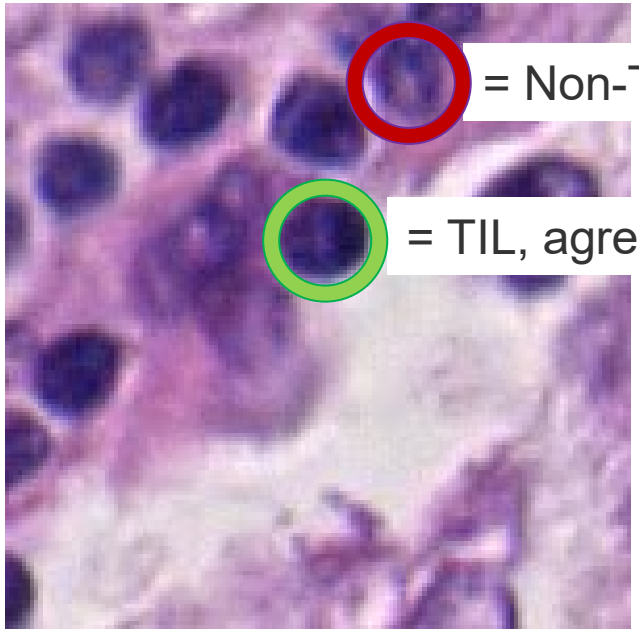
Training of expert-supervised deep learning algorithms



Detection of infiltrating immune cells (TILs) in hematoxylin-eosin stained tissue samples from patients with testicular cancer

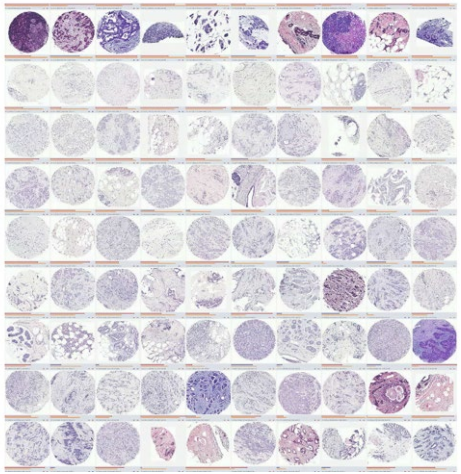
Training of expert-supervised deep learning algorithms

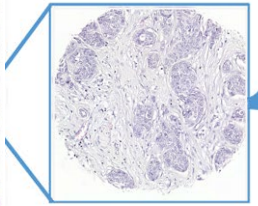
..AI results just as good as the annotator



TIL = tumor infiltrating lymphocyte

Outcome supervised learning for more precise AI-supported cancer diagnosis



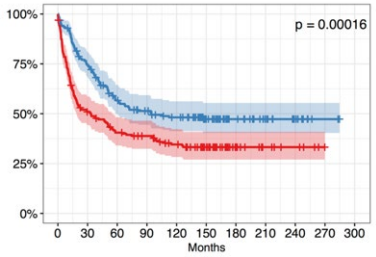


Digitized tissue samples from cancer patients with known outcome of cancer i.e. survivor or non-survivor

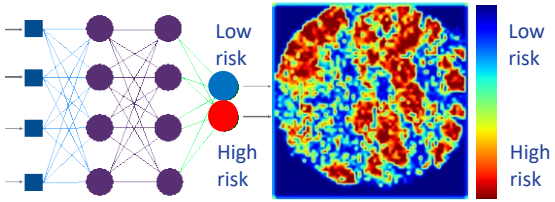
Outcome prediction by pathologists

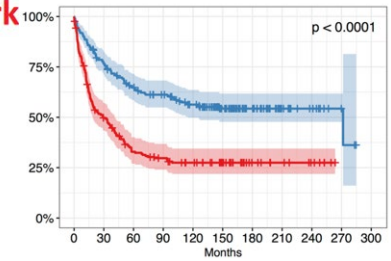
Low risk

High risk



Outcome prediction by deep network





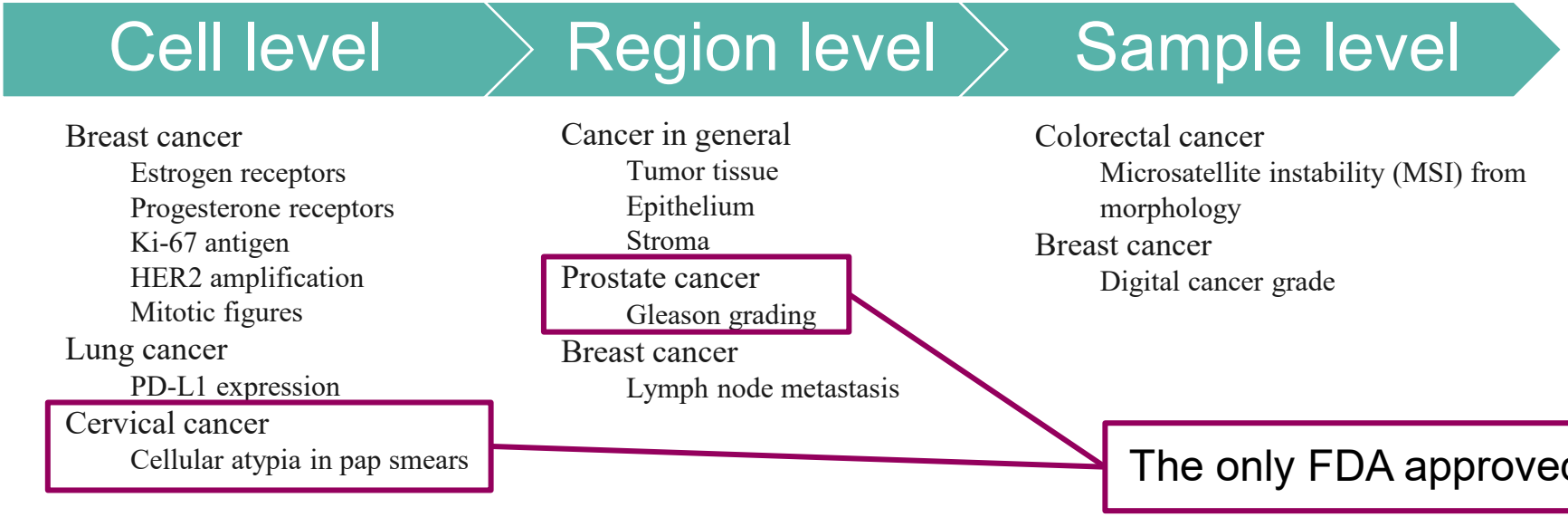
p-value <0.0001

Comparison of human expert-based and AI-based outcome prediction

Deep learning outperformed experienced pathologists in outcome prediction [1-3]

[1]Bychkov et al, Scientific Reports 2018;8:3395 [2]Turkki et al, Breast Can Res Tr 2019;177:41-52 [3]Bychkov et al, J Pathol Informatics 2022;13:9

AI algorithms for pathology in clinical use today*



*CE marked or CE-IVDR in Europe

Examples of combinations of AI and mobile technologies

AI-based diagnostics in a primary health care setting - the MoMic Project

Johan Lundin

THE SUNDAY TIMES | Today's sections | Past six days | My articles

Scotland

Cancer crisis looms due to lack of experts

Dearth of Scots specialists slowing treatment

INDY/PULSE

CANCER SURVIVAL RATES HAMPERED BY SHORTAGE OF NHS PATHOLOGISTS

China Struggling to Keep Up with Demand for Anatomic Pathologists

Dec 15, 2017 | Instruments & Equipment, Laboratory Hiring & Human Resources, Laboratory Management and Operations, Laboratory News, Laboratory Operations, Laboratory Pathology, Laboratory Testing, Management & Operations

Health

Shortage of pathologists burden on healthcare—Lancet

By Judd-Leonard Okafor | Publish Date: Mar 16 2018 2:51PM

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/ VÄSTERNORRLAND

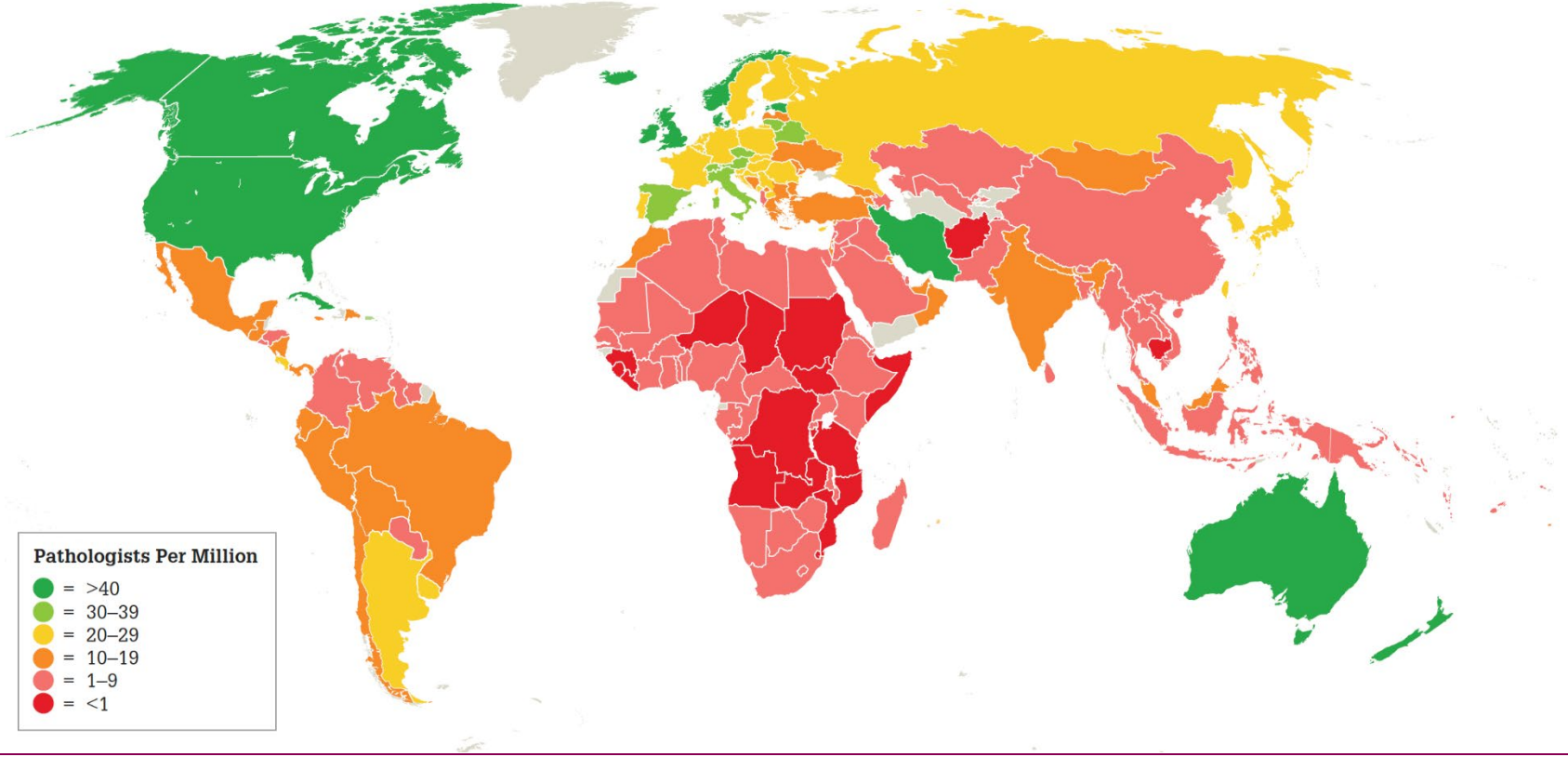
Cancer care suffers from a lack of pathologists

THE CITIZEN | ELECTION RESULTS 2015 | TANZANIA ELECTIONS 2015 | NEWS | MAGAZINES

SATURDAY, AUGUST 23, 2014

Tanzania short of pathologists, says Zanzibar President

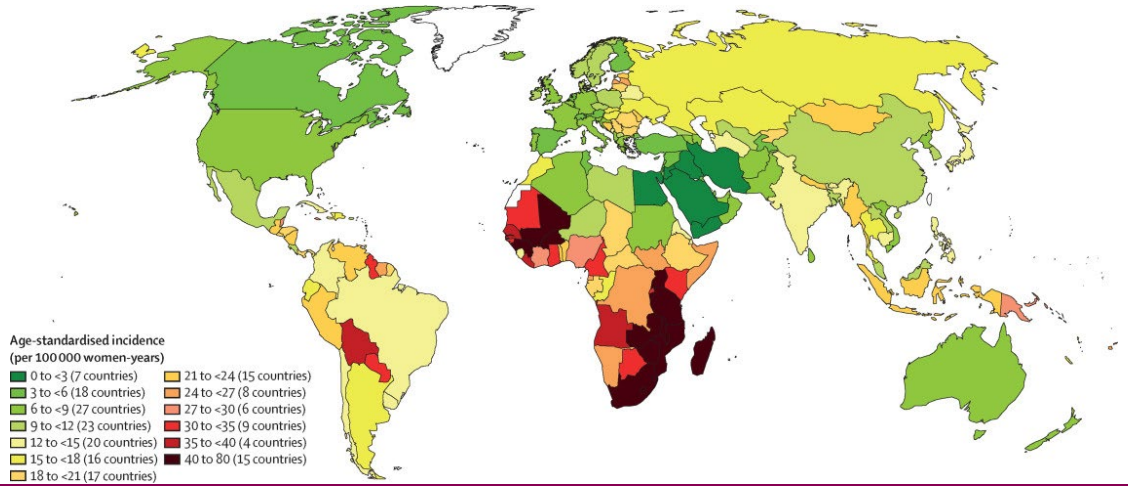
Shortage of Pathologists



Pathologist workforce worldwide

Cervical cancer from a global perspective

- Approximately 570,000 cases and 311,000 deaths globally in 2018
- The most common cause of cancer death in 36 LMIC countries
- Human papilloma virus (HPV) is a leading cause, but HPV vaccine will take decades to be fully realized



Incidence of cervical cancer /100.000 females (Globocan 2018, WHO)

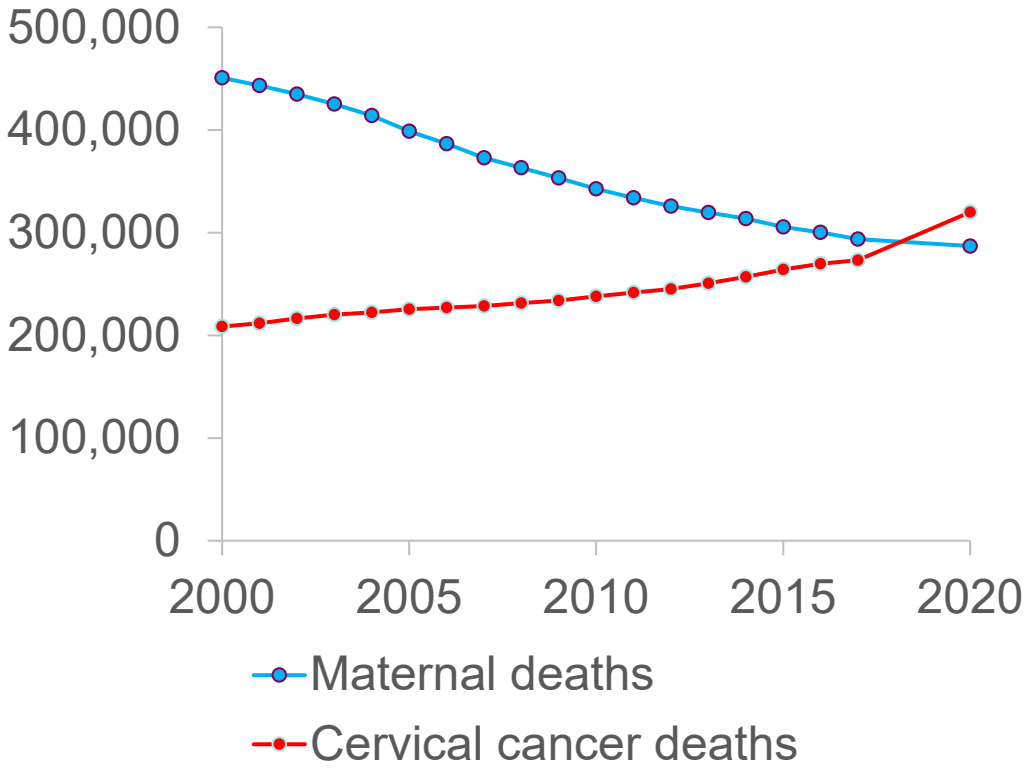
The problem

Cervical cancer is preventable via HPV vaccination, early detection of HPV infections and pre-cancerous lesions in the cervix e.g. via analysis of pap smears

But: An estimated 1.6 billion (67%) of 2.3 billion women aged 20–70 years, have never been screened for cervical cancer[1] and only 20% have been vaccinated by age 15

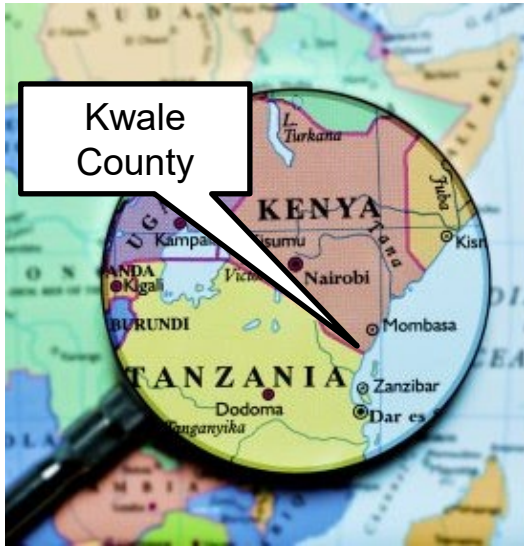
[1]Bruni L et al. Lancet Glob Health. 2022 Aug;10(8):e1115-e1127

Global number of maternal vs cervical cancer deaths*



*Data from IHME, Global Burden of Disease and WHO

Clinical studies on digital microscopy with AI at Kinondo Kwetu Hospital in Kwale County, Kenya



Hospital CEO
Harrison Kaingu

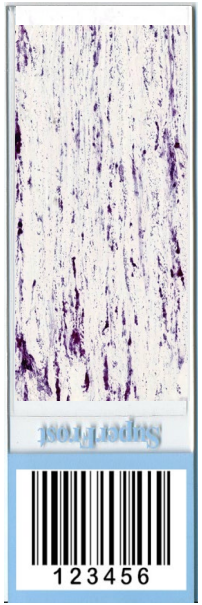
Digital diagnostic lab at Kinondo Kwetu Hospital

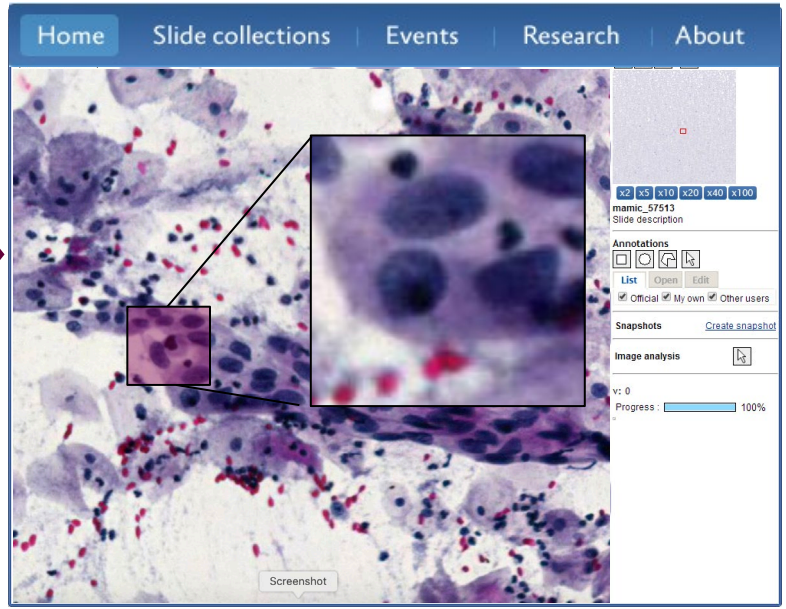
Nurses Carolyne and Priscillah

Laboratory technician Felix with equipment for staining

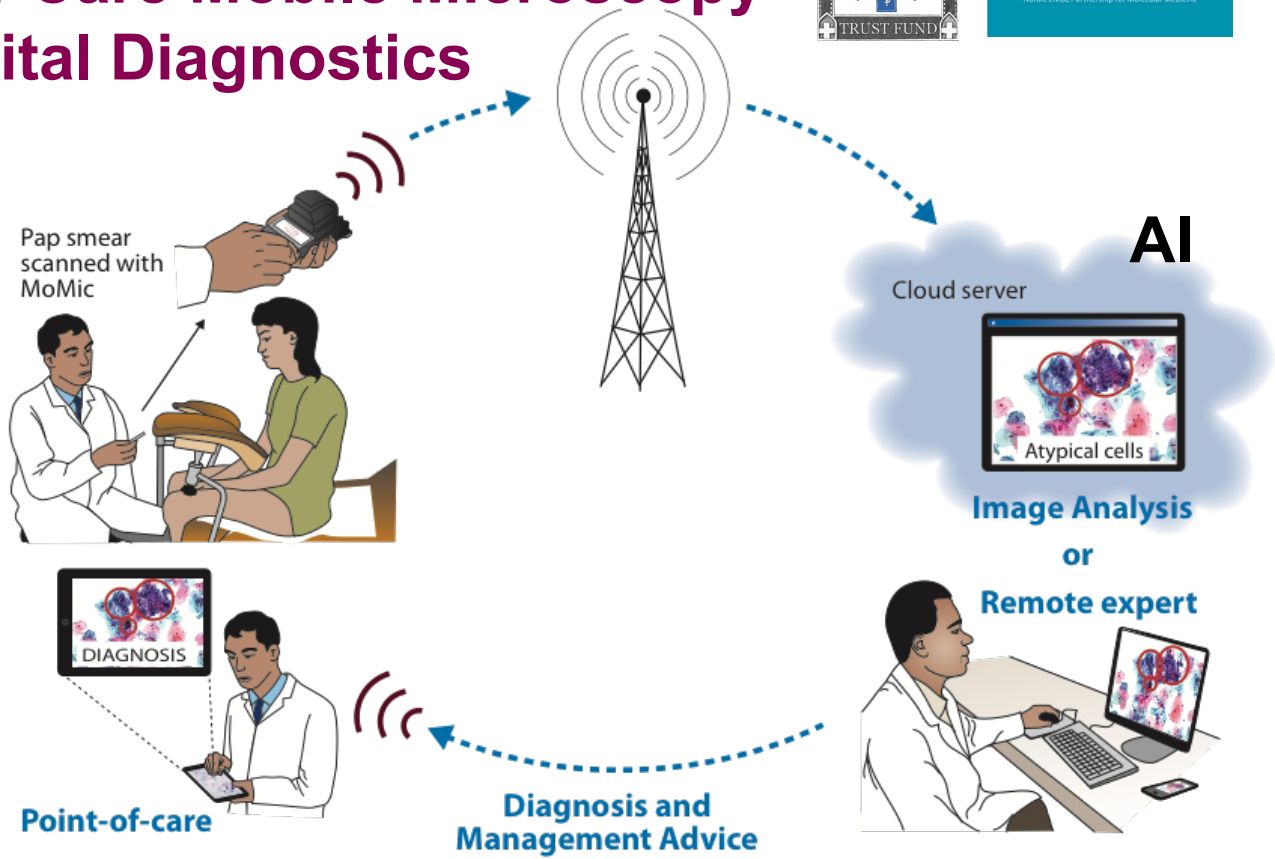
Slide scanner and uploading of digital slides over 3G/4G network

Digital microscopy and AI using minimal infrastructure – whole-slide imaging at and mobile upload to cloud



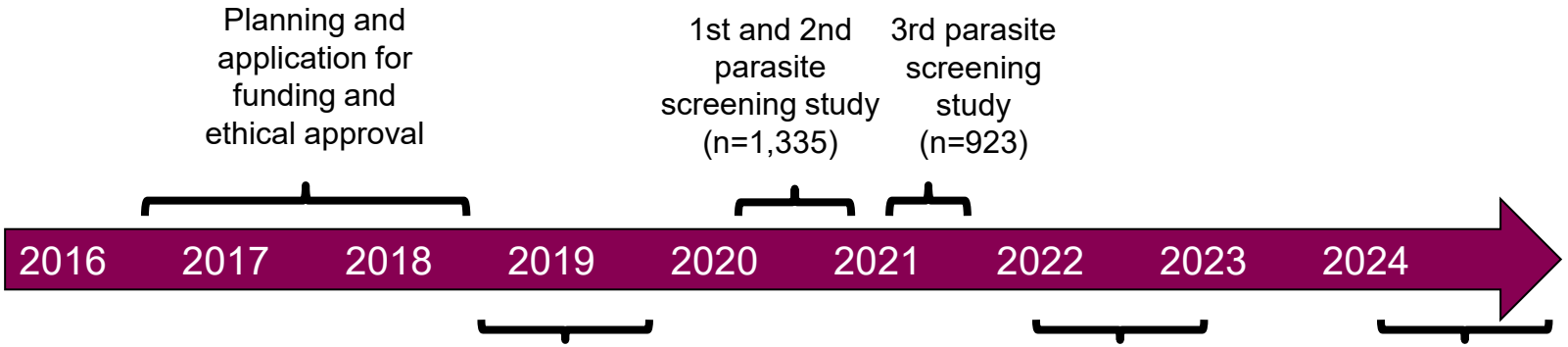


Point-of-Care Mobile Microscopy and Digital Diagnostics



Studies on AI-supported diagnostics at the point-of-care in Kenya and Tanzania

School-aged children screened for soil-transmitted helmints in stool (n=2,258)



Women screened for pre-cancerous lesions in cervical smears (n=3,742)

Proof of concept study

- Cervical smears from 740 women aged 18-64 years within an HIV control program were collected between 09/2018 and 09/2019 at the Kinondo Hospital in rural Kenya
- Samples were prepared as conventional smears and stained with a Pap stain and digitized with a portable scanner
- 350 digitized pap smears for training the algorithm and 361 samples for validation

JAMA Network Open

Original Investigation | Pathology and Laboratory Medicine

March 17, 2021

Point-of-Care Digital Cytology With Artificial Intelligence for Cervical Cancer Screening in a Resource-Limited Setting

Oscar Holmström, MD, PhD[1]; Nina Linder, MD, PhD[1,2]; Harrison Kaingu, BS[3]; Ngali Mbuuko, MD[3]; Jumaa Mbete, MD[3]; Felix Kinyua, MS[3]; Sara Törnquist, RNM[4]; Martin Muinde, GDip[3]; Leena Krogerus, MD, PhD[5]; Mikael Lundin, MD[1]; Vinod Diwan, MD, PhD[4]; Johan Lundin, MD, PhD[1,4]

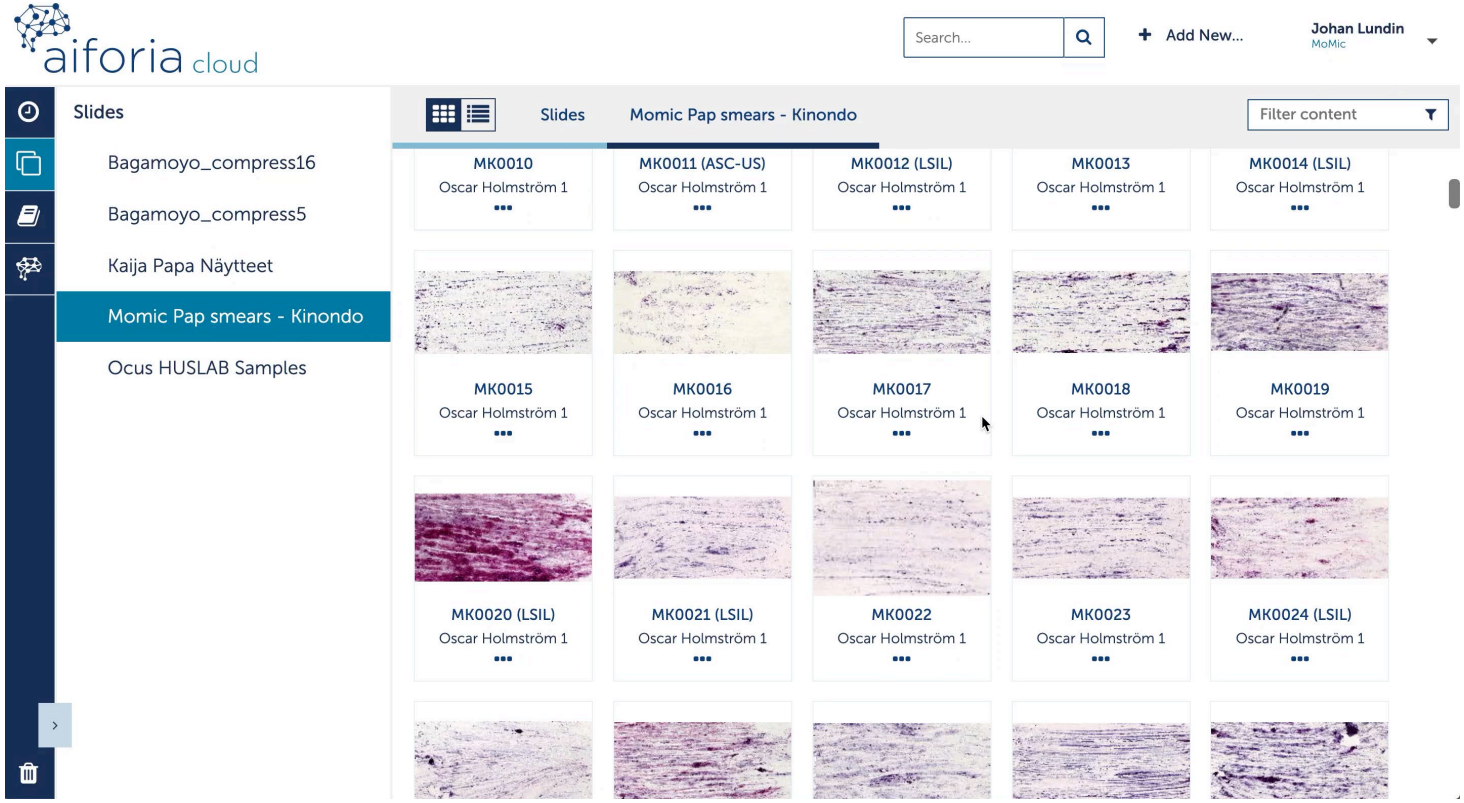
Author Affiliations | Article Information

JAMA Netw Open. 2021;4(3):e211740. doi:10.1001/jamanetworkopen.2021.1740

Holmström et al. JAMA Network Open. 2021;4(3):e211740.

Results of the MoMic Cervical Cancer Screening

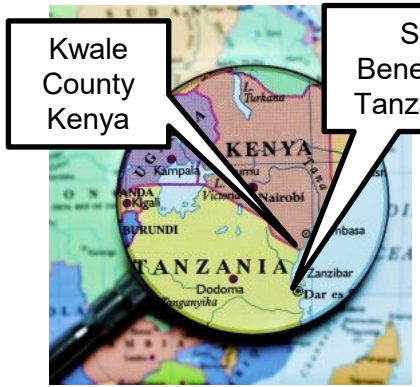
- **Training on 350 samples**
- **Validation on 361 samples**
- **Sensitivity** 96%-100%
- **Specificity** 93%-99% for high-grade and 82%-86% for low-grade
- no slides manually classified as high grade were incorrectly classified as negative.



Holmström et al. JAMA Network Open. 2021;4(3):e211740.

2nd and 3rd validation study on cervical cancer screening

- Cervical smears from 3,000 women aged 18-64 years within HIV control programs and from the general population were collected between 02/2022 and 12/2024 in Kwale County, Kenya and Dar Es Salaam, Tanzania
- Samples were prepared as pap smears and stained with a Pap stain and digitized with a portable scanner. HPV status also analysed.
- Results of the AI are being analysed and a report prepared
- All women with significant cell findings are subject to further diagnostics and treatment, typically local treatment of the cervix



Pictures from Women's Health Camp i Kinondo 2/2024

>600 women attended in 3 days

The Star, Kenya, 4/2024

BIG READ /MEDICAL TECHNOLOGY

HOW A HOSPITAL BOOSTED THE HEALTH OF KWALE COMMUNITY

It has offered thousands free AI cancer treatment since 2018

SHABAN OMAR
@TheStarKenya

Mwanamisi Salim and Patience Kanga have just come for a free cervix and breast cancer screening at the Kinondo Kwetu Hospital in Kwale county.

The exercise is one of the facility's numerous free treatment camps designed to improve community health.

In the event they test positive, Salim, Kanga and hundreds of other women are guaranteed to receive all the services they require for free.

The hospital has adopted artificial intelligence for cancer diagnosis.

Technology is playing an important role in saving and improving the lives of locals, particularly women who have suffered and sweat for cancer treatment.

Some have died as a result of cervical and breast cancer, leaving their families devastated.

Thousands of locals have benefited from AI cancer treatment technology since the pilot project was implemented at the health facility in 2018 in the county.

Kinondo Kwetu is a privately owned hospital that began as a small

Kinondo Kwetu hospital director Harrison Kaingu in his office in Kwale county on February 20 /SHABAN OMAR

Karolinska Institute medical technology professor Johan Lundin /SHABAN OMAR

NCDs county coordinator Noreen Zecha /SHABAN OMAR

appeared for cancer screening were found to have cancer.

He said that frequent screening can lead to early detection and treatment of the disease to save lives.

Karolinska Institutet medical technology professor Johan Lundin said compared to human expertise, AI has made significant improvements in detecting abnormal cells in a cervical pap smear.

"The screening results are more accurate compared to a human expert," he said. "The accuracy is approximately 95 per cent due to high-quality results."

The health expert said more than 1,500 women have been successfully screened at the Kinondo health facility using the technology.

He said the technology presents a significant opportunity to address the pathologist shortage not only in African countries but globally, as well as to improve cancer diagnosis.

Lundin said the technology can be trained to create a virtual expert to assist human specialists with remarkable efficiency and speed.

He said the expert can access the technology even in remote areas by simply looking at the results of the AI and transforming the findings, making technology in the general community.

While AI is widely used in many medical research projects, he said, it has not yet been widely adopted in clinical medicine.

PROSTHETICS AVAILABLE

The hospital is one of the few health facilities in Kenya that offer prosthetic services.

The prosthetic limbs are designed using a 3D imaging technique, and the hospital can produce four legs per day.

Noreen Zecha, the county coordinator for non-communicable diseases, said the county intends to reduce cervical and breast cancers by 90 per cent by 2030 and ensure the affected victims get the right medication on time.

The county is partnering with various stakeholders in several fields to provide improved and affordable healthcare services to the common citizens at their doorstep.

Cancer screenings are ongoing in all county health facilities and cancer diagnosis will become more effective as the oncology centre nears completion, she said.

At the moment, the county government is giving HPV vaccines to

Resident Mwanamisi Salim speaks in an interview at Kinondo Kwetu healthcare facility in Msambweni, Kwale county, on February 20 /SHABAN OMAR

with which cancer patients receive treatment.

The hospital runs feeding programmes in some primary schools to assist in matters of nutrition among children.

One of the beneficiaries is Kinondo Primary School, where the hospital constructed a borehole and initiated a kitchen garden programme.

support the surrounding community and their children to achieve good lifestyles and health.

He said a huge percentage of the community lives in poverty and can't afford three meals a day or quality healthcare services.

Kaingu said the hospital played a key role in bridging the gap and bringing treatment closer to the

New Scientist

MoMic
Artificial intelligence for diagnostics

MUHAS

KINONDO KWETU TRUST FUND

FIMM
Institute for Molecular Medicine Finland
Nordic EMBL Partnership for Molecular Medicine

UPPSALA UNIVERSITET

KAROLINSKA INSTITUTET ANNO 1810

Karolinska Institutet

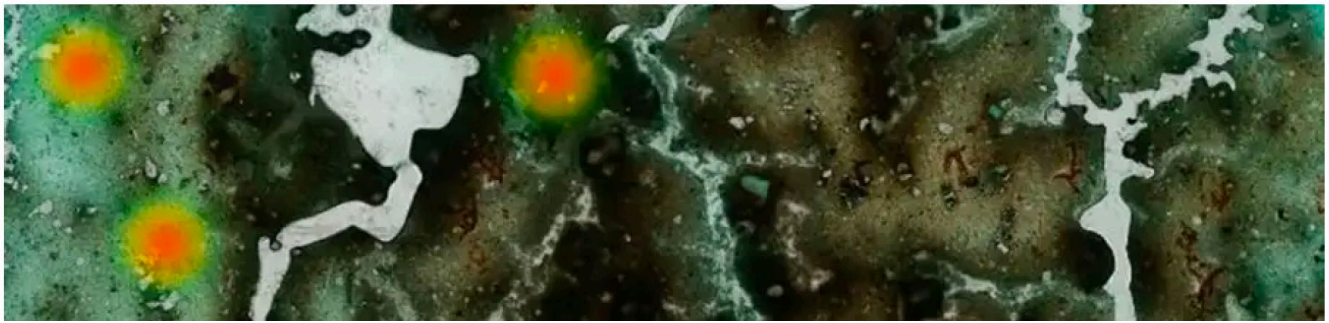
Technology

AI can spot parasites in stool samples to help diagnose infections

About 1.5 billion people worldwide carry a risk of conditions including malnutrition because of parasitic infection, and AI could help identify those affected

By Jeremy Hsu

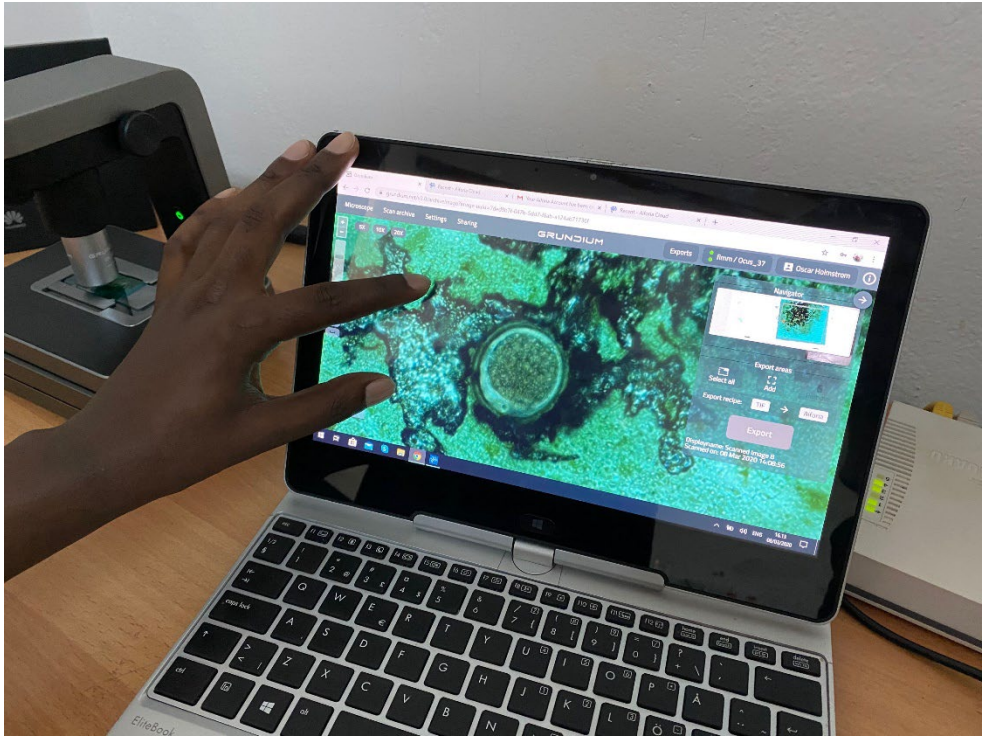
11 April 2024



Lundin et al, PLOS NTDS 2014

Field study on diagnostics of soil-transmitted helminths in Kwale County, Kenya

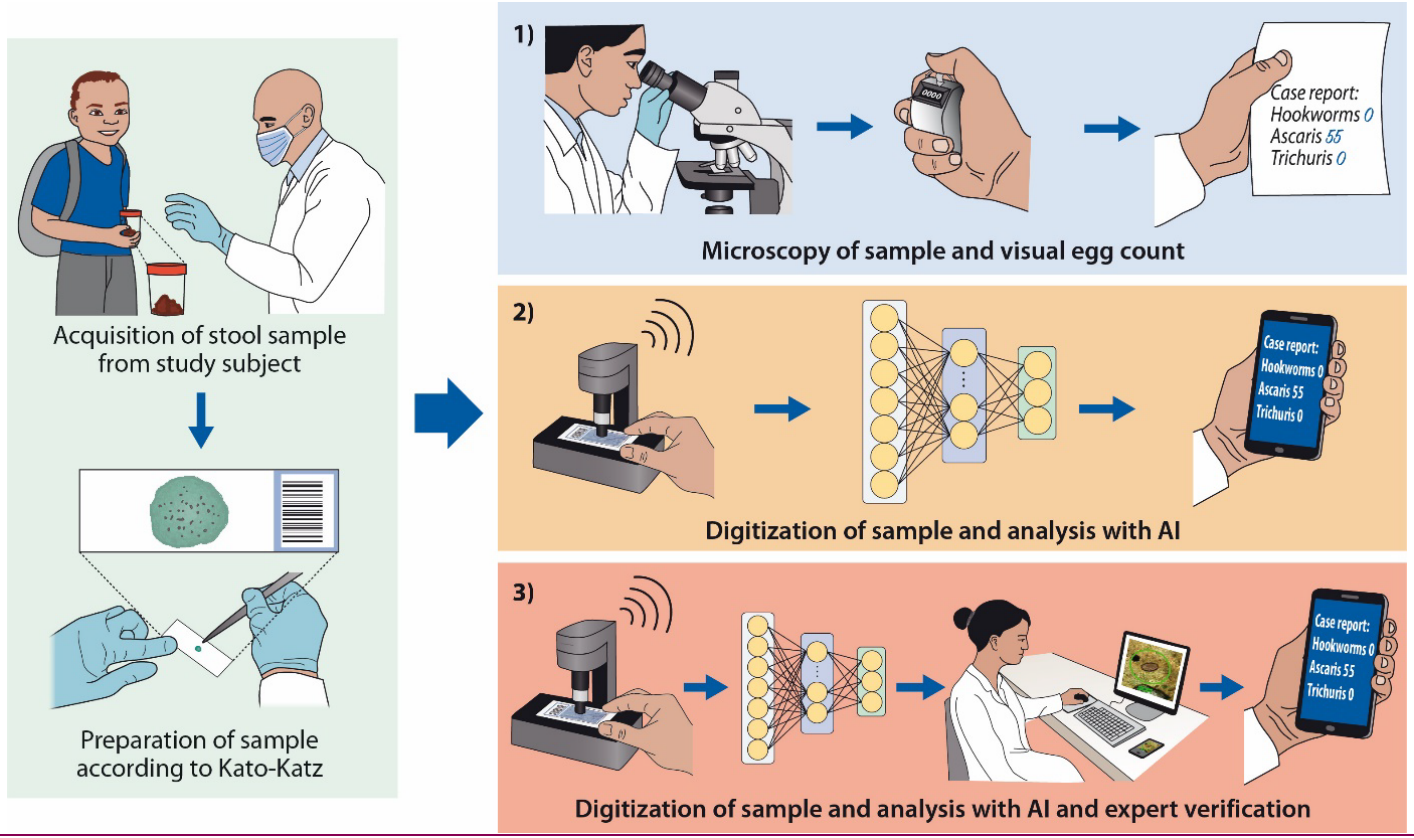
- School-children at primary schools in a high prevalence region in Kwale County
- 2,258 stool samples collected
- Prepared according to the established Kato-Katz method
- Scanned with a mobile microscope scanner and WSIs uploaded to the cloud for AI analysis
- The sensitivity of the expert verified AI for *A. lumbricoides*, *T. trichiura* and hookworm was 100%, 94% and 92%, respectively
- Children with infection treated



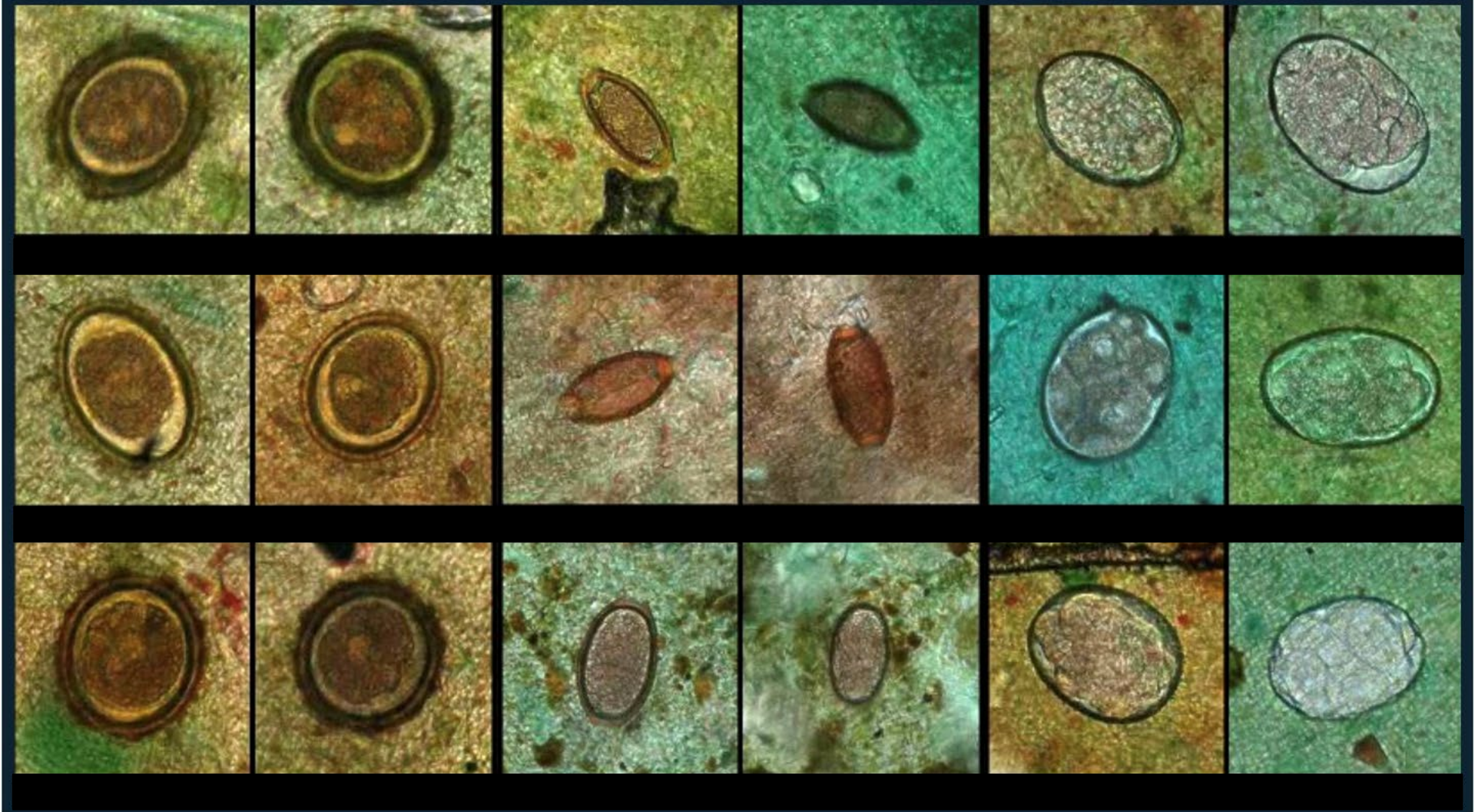
Lundin et al, PLOS NTDS 2024 and von Bahr et al, in manuscript

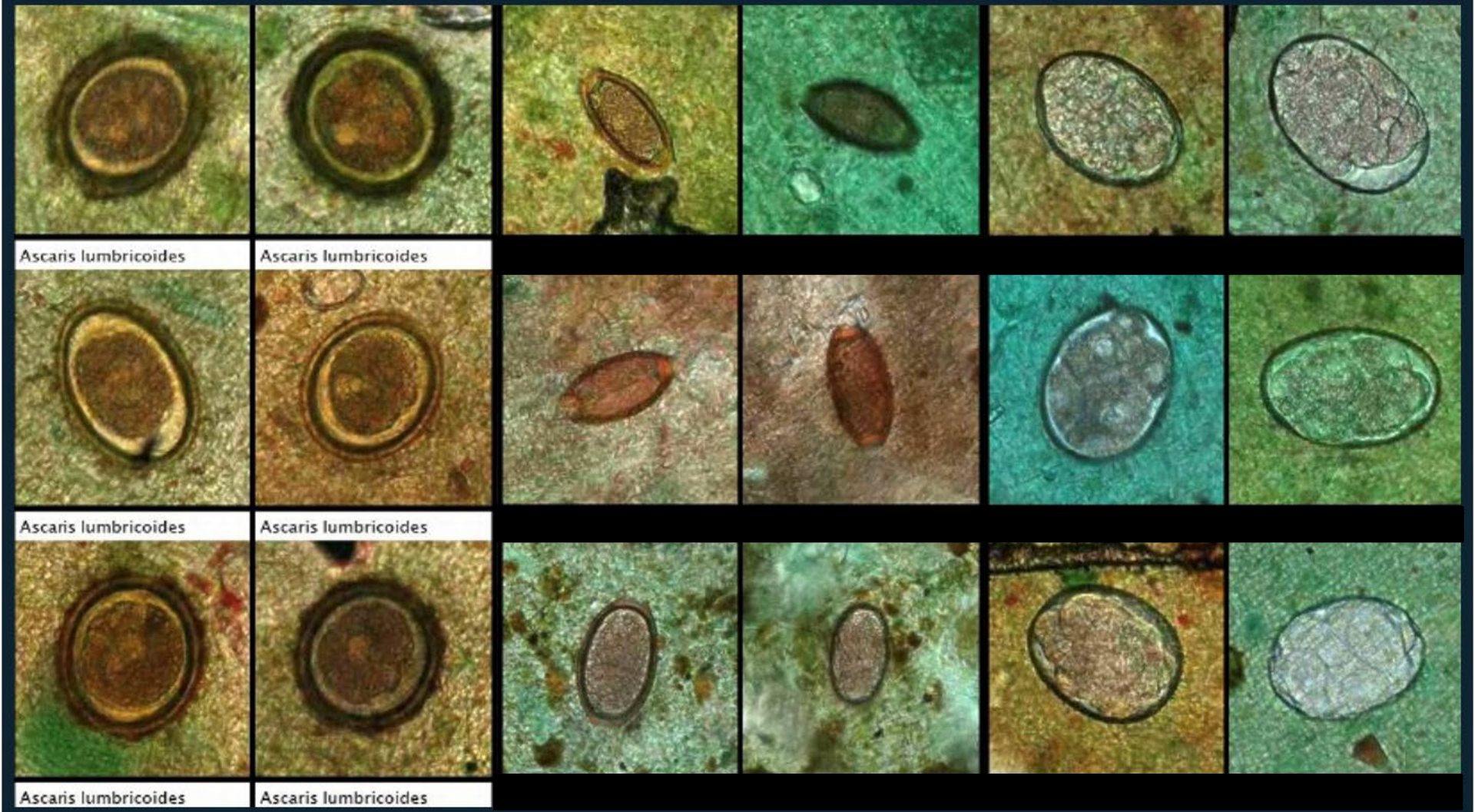
AI detects helminth eggs in stool sample

- Algorithm trained to detect ascaris, trichuris and hookworms
- As a result: all the yellow dots are trichuris eggs
- Exact number of the different egg types are calculated
- Finds parasite eggs in 10% more samples than the human observer, especially in low intensity infections



Manual microscopy vs autonomous AI vs expert-verified AI

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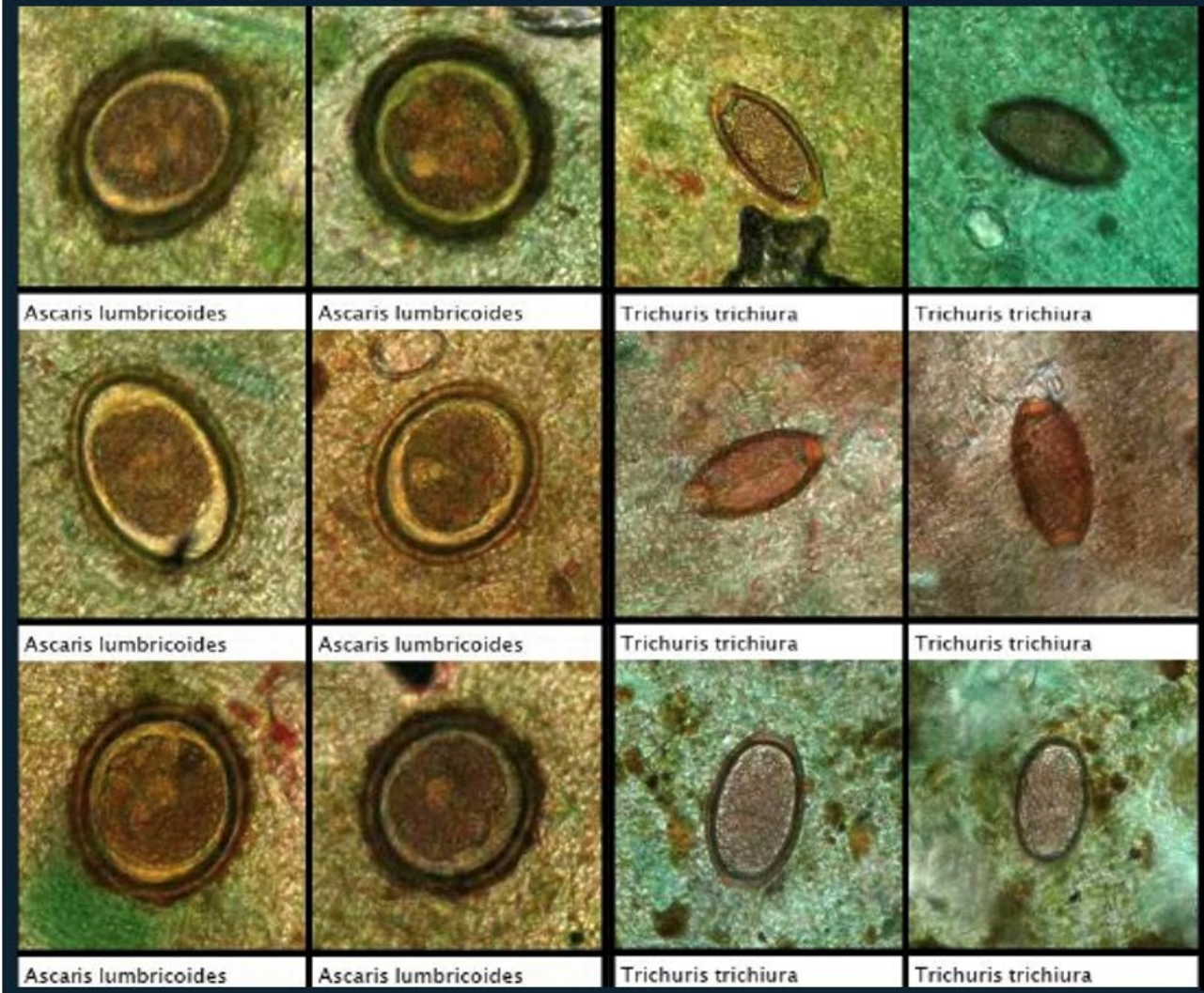
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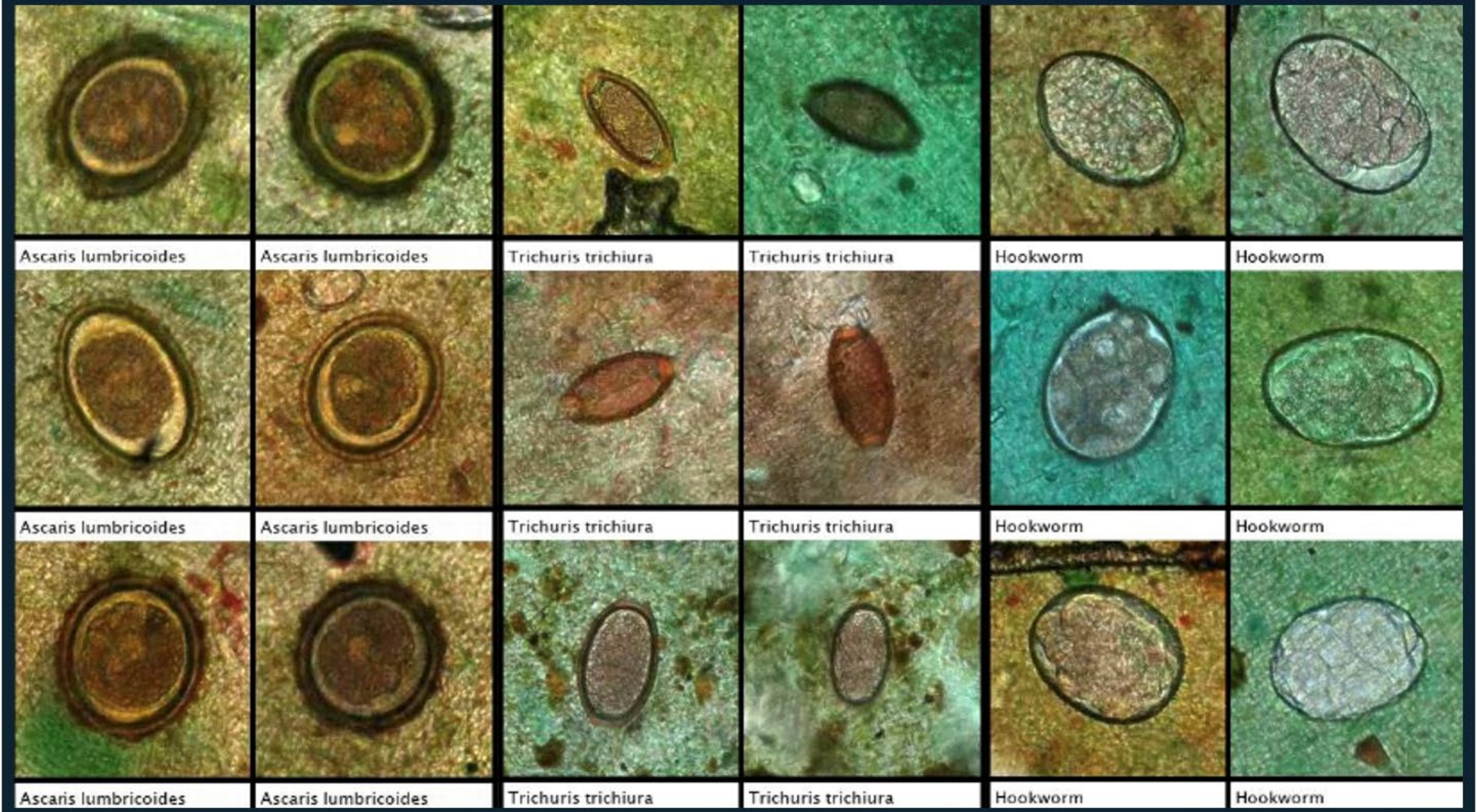
Ascaris lumbricoides
Ascaris lumbricoides
Trichuris trichiura
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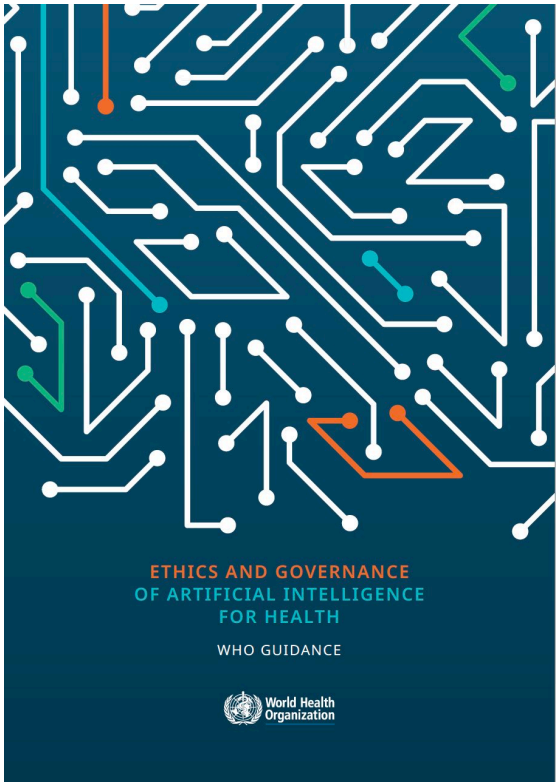
Ascaris lumbricoides
Ascaris lumbricoides
Trichuris trichiura
Trichuris trichiura
Hookworm
Hookworm

WHO Guidance on the use of AI for health - six key principles [1]

- Protect autonomy
- Promote human safety
- Ensure transparency
- Foster accountability
- Ensure equity
- Promote AI that is sustainable



1. World Health Organization. Ethics and governance of artificial intelligence for health: WHO guidance. 2021.

Conclusions

- Digital diagnostics with AI-based algorithms can be applied in resource-limited settings using a bottom-up, minimal infrastructure approach
- Mobile technologies allow AI-diagnostics to be performed in remote settings and at the point-of-care, given that a high-quality sample can be prepared
- AI-based diagnostics is likely to improve access to high-quality diagnostics, but need to be cost-efficient, monitored and augmented with data from multiple labs and geographical locations

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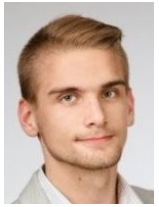

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Artificial intelligence for diagnostics

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Thank you!