Low-cost healthcare solutions for tuberculosis screening and pregnancy risk prediction using X-ray, ultrasound and deep learning

2020 Joint AAPM/COMP Meeting
Vancouver, BC
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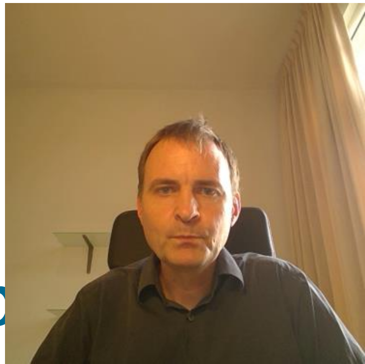
Bram van Ginneken

Diagnostic Image Analysis Group, Radboud University Medical Center; Fraunhofer MEVIS, Bremen; Thirona, Nijmegen

Radboud

Disclosures

- Developer CAD4TB (Delft Imaging): royalties & funding
- Co-founder and CSO Thirona: stock, royalties & funding
- Developer Veolity (MeVis Medical Solutions) & DynaCAD Lung (InVivo): royalties & funding
- ScreenPoint is a spin-off from DIAG; DIAG receives royalties & funding
- DIAG funding: Canon, Siemens Healthineers, Philips Medical, Elekta, Sectra, Novartis



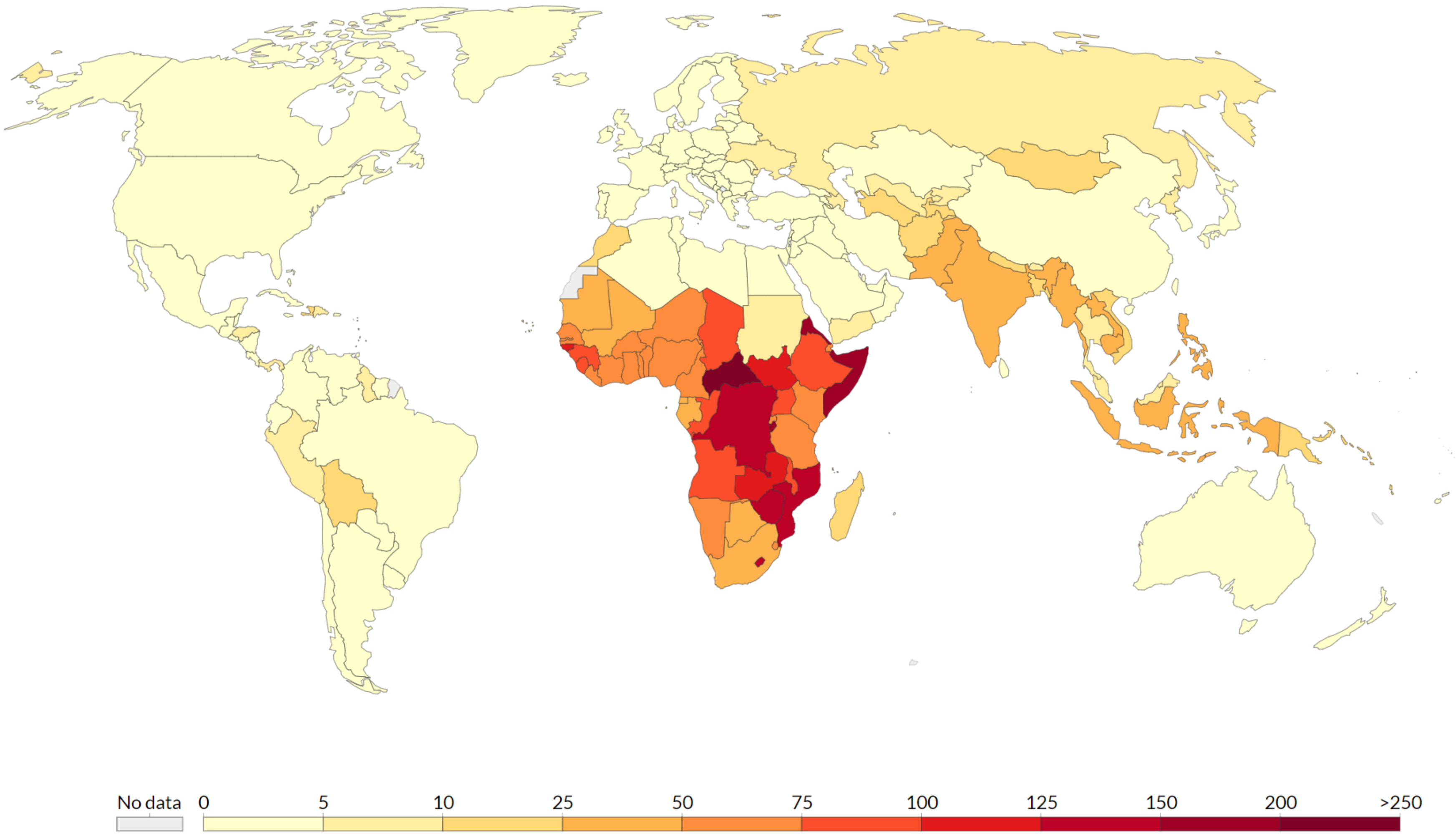
Tuberculosis: 4500 deaths per day

Death rate from tuberculosis, 2017

The annual number of deaths from tuberculosis per 100,000 people.

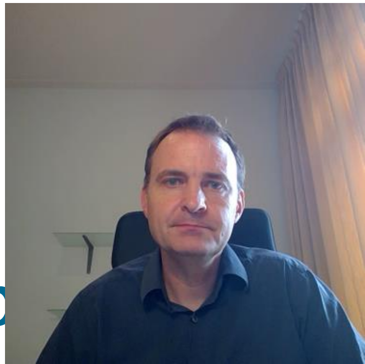
Our World in Data

World



Source: IHME, Global Burden of Disease (2017)

OurWorldInData.org/causes-of-death • CC BY

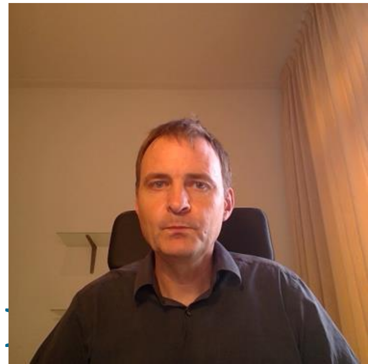


Tuberculosis

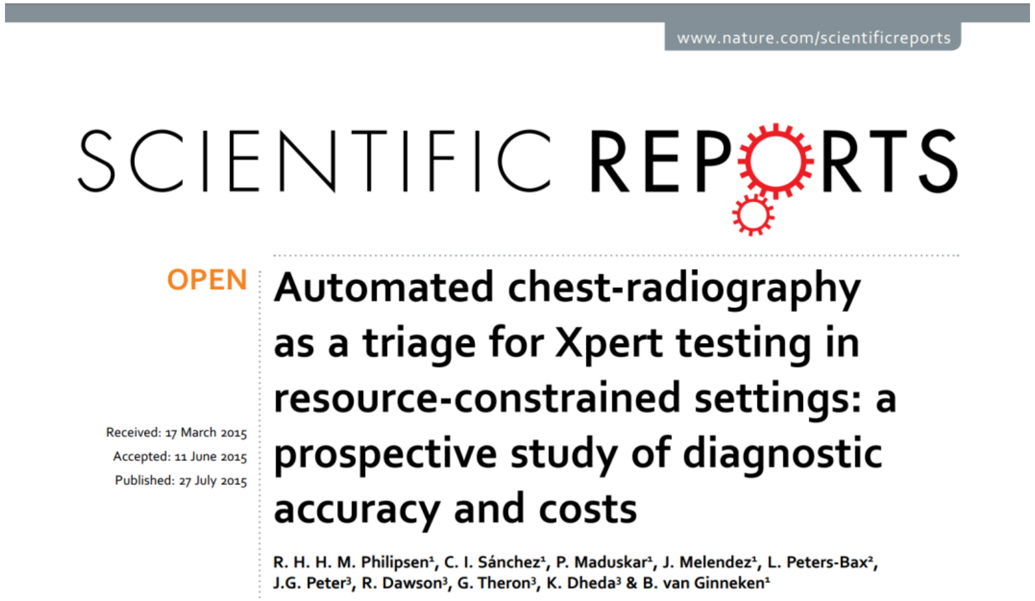
- Bacterial infection
- Diagnosed by RT-PCR
- PCR test is expensive and time consuming and not always available
- ~4500 deaths/day
- Kills old, very young and the working population
- Affects mainly poor countries/regions
- No vaccine (despite decades of effort)
- Cheap and effective cure ($10)
- X-ray imaging can screen quickly

COVID-19

- Viral infection
- Diagnosed by RT-PCR
- PCR test is expensive and time consuming and not always available
- ~4500 deaths/day currently
- Kills almost exclusively the old and very old population
- Affects the whole world
- No vaccine yet
- No cure
- X-ray imaging, CT and blood tests can screen quickly



Triaging with chest x-ray


www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

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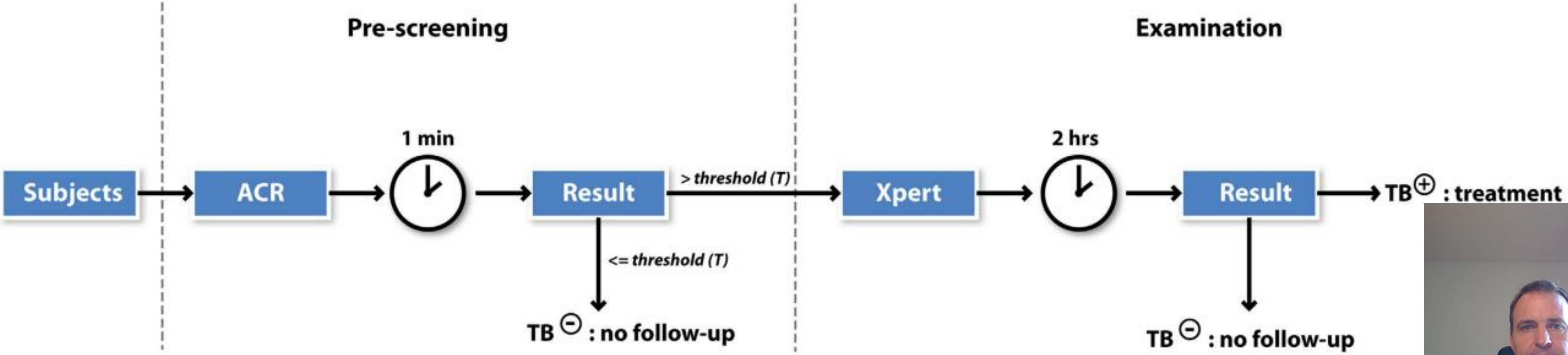
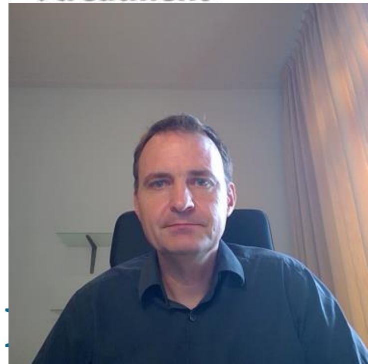
Accepted: 11 June 2015
Published: 27 July 2015

Automated chest-radiography as a triage for Xpert testing in resource-constrained settings: a prospective study of diagnostic accuracy and costs

R. H. H. M. Philipsen[1], C. I. Sánchez[1], P. Maduskar[1], J. Melendez[1], L. Peters-Bax[2], J.G. Peter[3], R. Dawson[3], G. Theron[3], K. Dheda[3] & B. van Ginneken[1]






ONE-STOP DetecTB service

TB IS CURABLE. EARLY TESTING AND
TREATMENT IS THE KEY TO STOPPING TB
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A Partnership of
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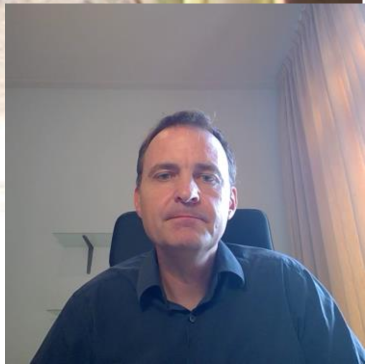
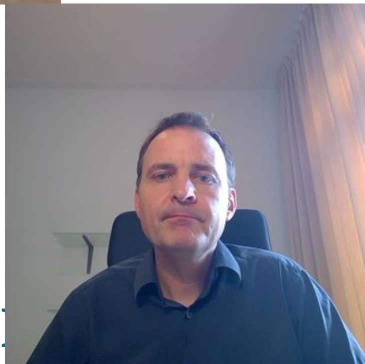
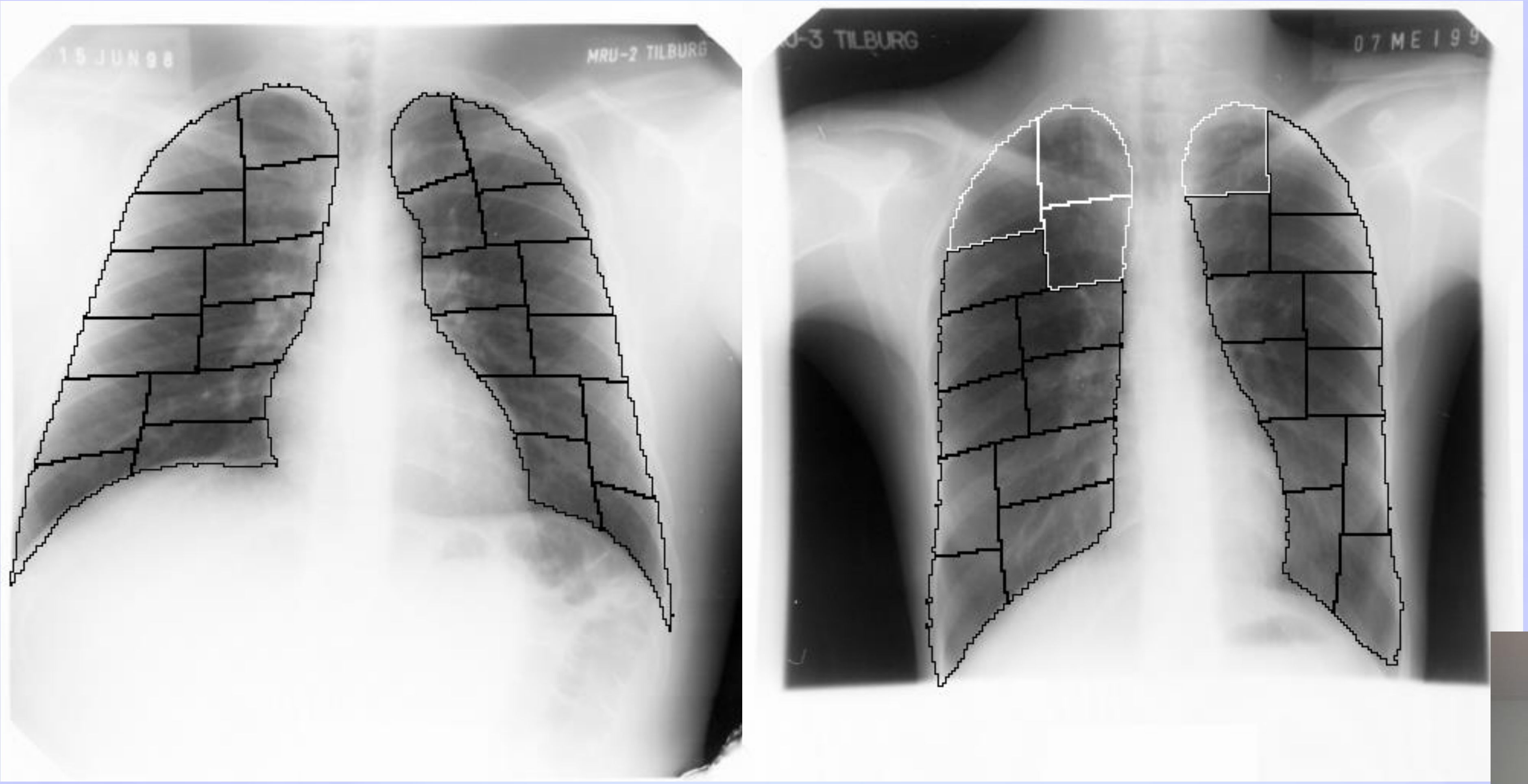


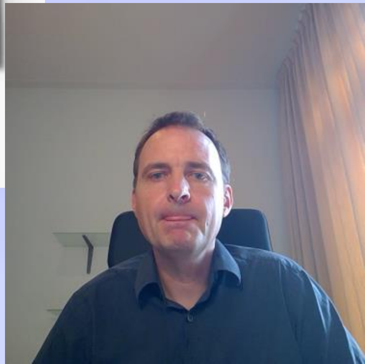

CAD4
Delft Light
backpack X-ray
DELFT
IMAGING SYSTEMS


Delft Light
backpack X-ray



Segmentation with Active Shape Models

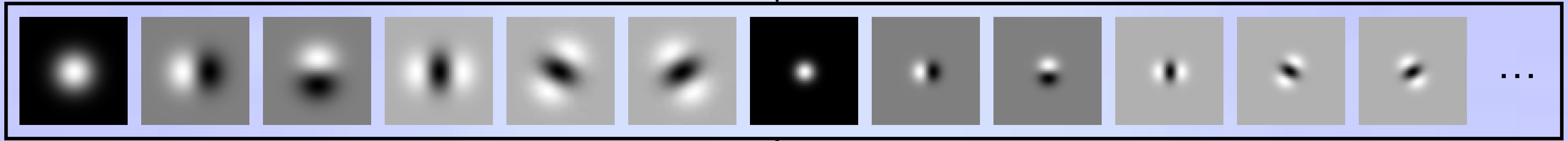




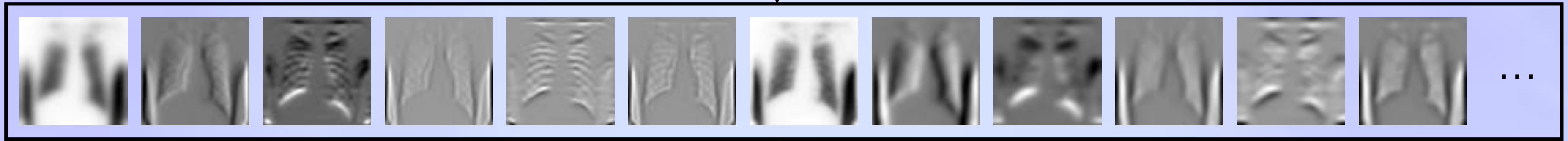
Texture feature extraction

Input image

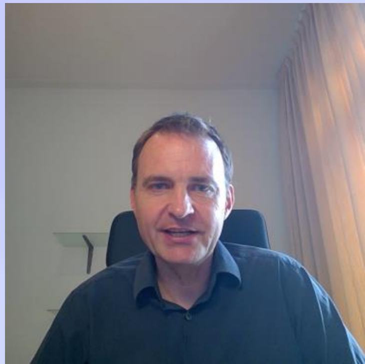
Filter bank of Gaussian derivatives at multiple orders, orientations, scales



measures the presence of blobs, edges, lines, of various sizes and orientations

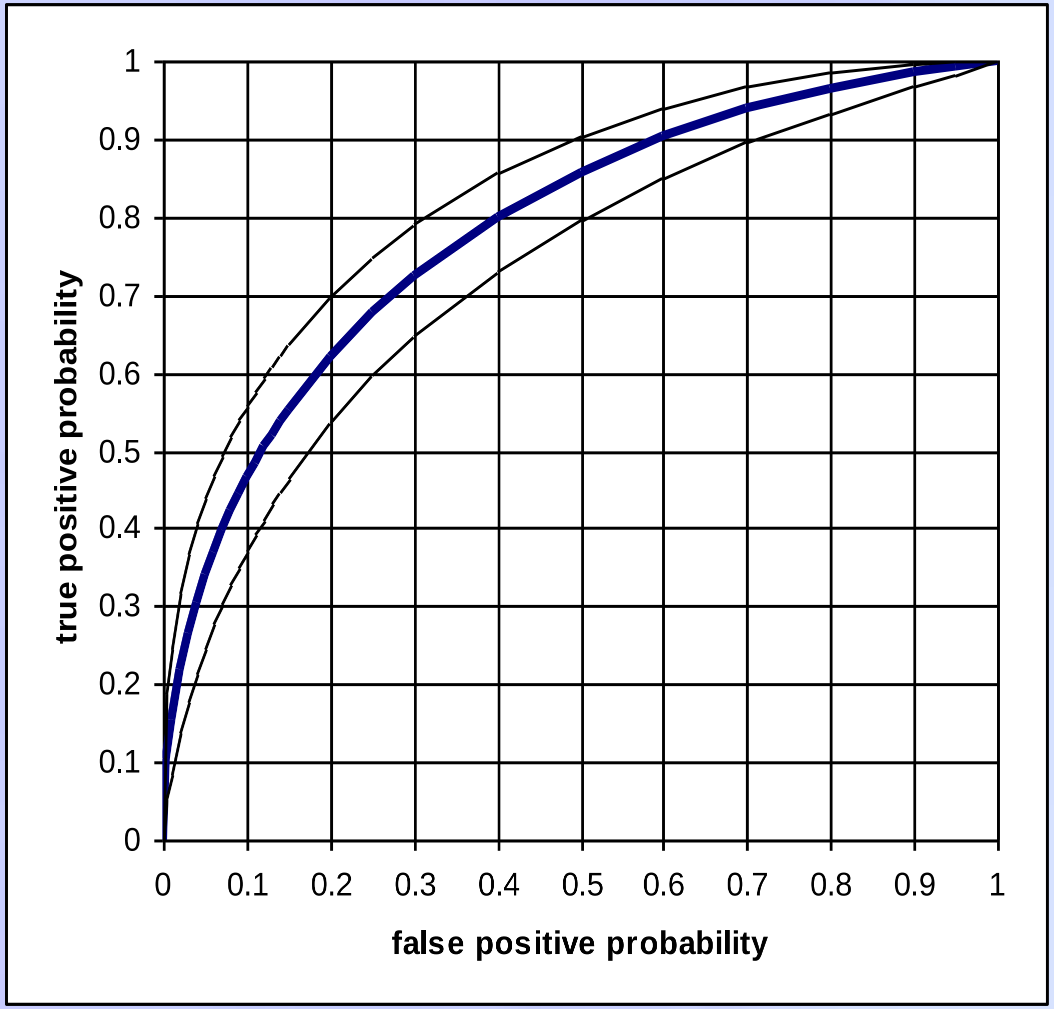


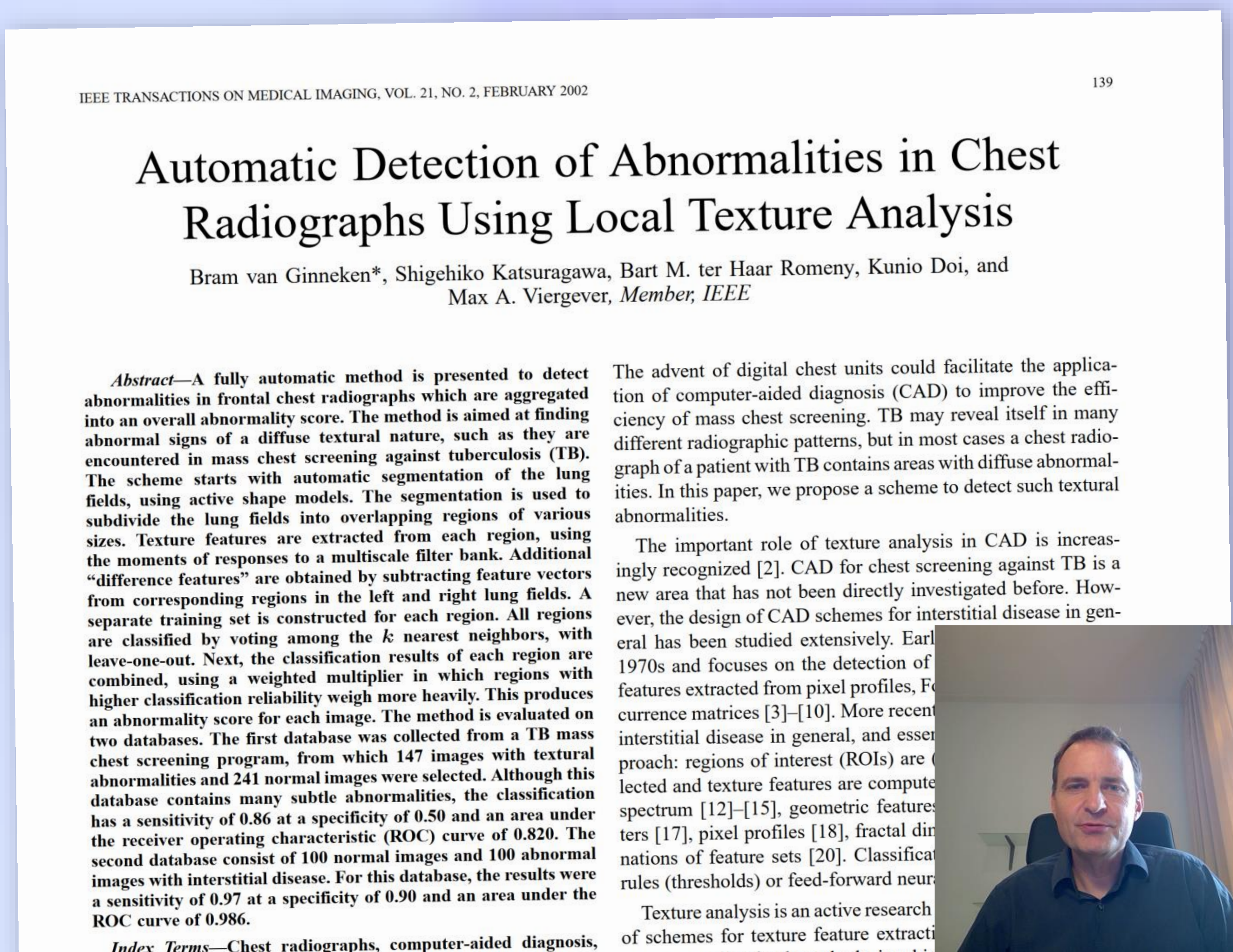
For each region of interest, a histogram of the response to each filter is computed.
Moments of each histogram (standard deviation, skew, kurtosis) are texture features.



Result for TB screening database

ROC curve for best performing feature set (A_z=0.820).





IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 21, NO. 2, FEBRUARY 2002 139

Automatic Detection of Abnormalities in Chest Radiographs Using Local Texture Analysis

Bram van Ginneken*, Shigehiko Katsuragawa, Bart M. ter Haar Romeny, Kunio Doi, and Max A. Viergever, *Member, IEEE*

Abstract—**A fully automatic method is presented to detect abnormalities in frontal chest radiographs which are aggregated into an overall abnormality score. The method is aimed at finding abnormal signs of a diffuse textural nature, such as they are encountered in mass chest screening against tuberculosis (TB). The scheme starts with automatic segmentation of the lung fields, using active shape models. The segmentation is used to subdivide the lung fields into overlapping regions of various sizes. Texture features are extracted from each region, using the moments of responses to a multiscale filter bank. Additional "difference features" are obtained by subtracting feature vectors from corresponding regions in the left and right lung fields. A separate training set is constructed for each region. All regions are classified by voting among the k nearest neighbors, with leave-one-out. Next, the classification results of each region are combined, using a weighted multiplier in which regions with higher classification reliability weigh more heavily. This produces an abnormality score for each image. The method is evaluated on two databases. The first database was collected from a TB mass chest screening program, from which 147 images with textural abnormalities and 241 normal images were selected. Although this database contains many subtle abnormalities, the classification has a sensitivity of 0.86 at a specificity of 0.50 and an area under the receiver operating characteristic (ROC) curve of 0.820. The second database consist of 100 normal images and 100 abnormal images with interstitial disease. For this database, the results were a sensitivity of 0.97 at a specificity of 0.90 and an area under the ROC curve of 0.986.**

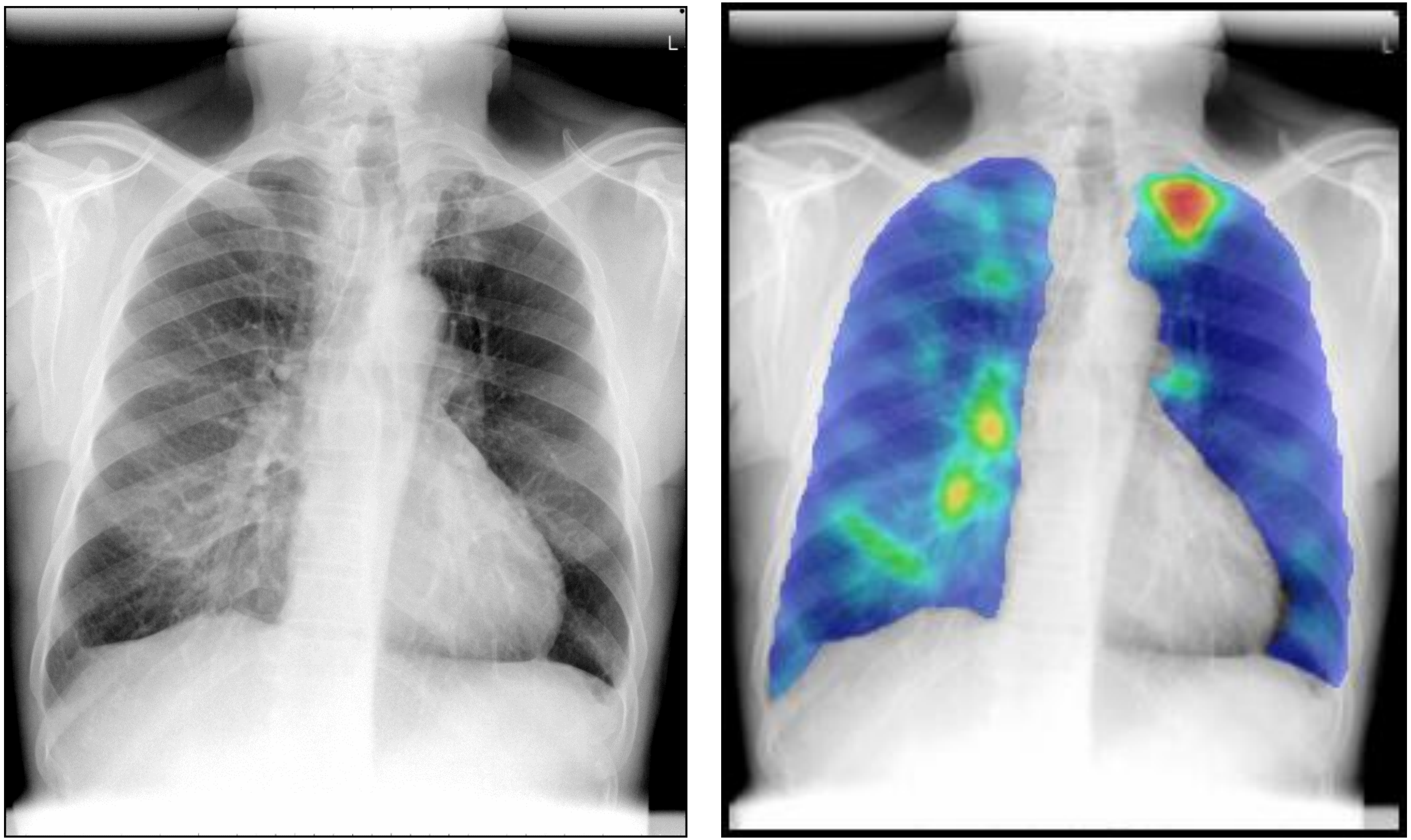
Index Terms—**Chest radiographs, computer-aided diagnosis,**

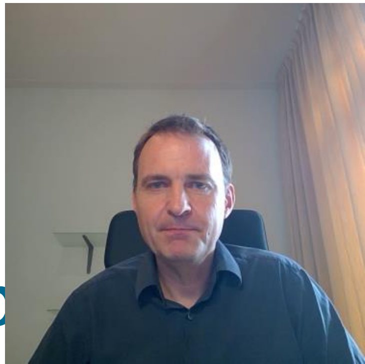
The advent of digital chest units could facilitate the application of computer-aided diagnosis (CAD) to improve the efficiency of mass chest screening. TB may reveal itself in many different radiographic patterns, but in most cases a chest radiograph of a patient with TB contains areas with diffuse abnormalities. In this paper, we propose a scheme to detect such textural abnormalities.

The important role of texture analysis in CAD is increasingly recognized [2]. CAD for chest screening against TB is a new area that has not been directly investigated before. However, the design of CAD schemes for interstitial disease in general has been studied extensively. Earl 1970s and focuses on the detection of features extracted from pixel profiles, F currence matrices [3]–[10]. More recent interstitial disease in general, and essen proach: regions of interest (ROIs) are lected and texture features are compute spectrum [12]–[15], geometric features ters [17], pixel profiles [18], fractal din nations of feature sets [20]. Classificat rules (thresholds) or feed-forward neur

Texture analysis is an active research of schemes for texture feature extracti

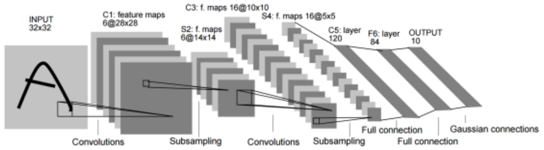
Detection of tuberculosis



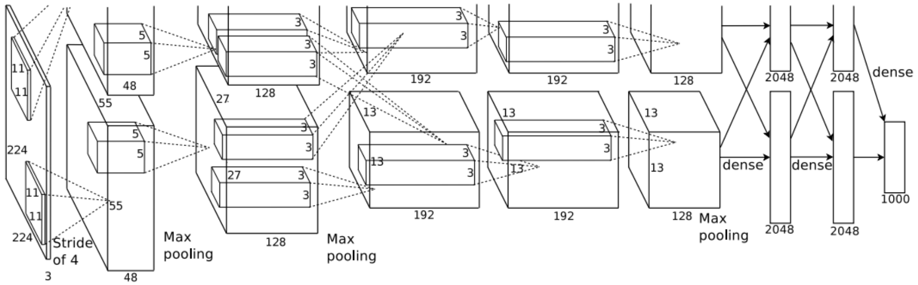


Input: image. Output: number(s). Classifier/discriminator

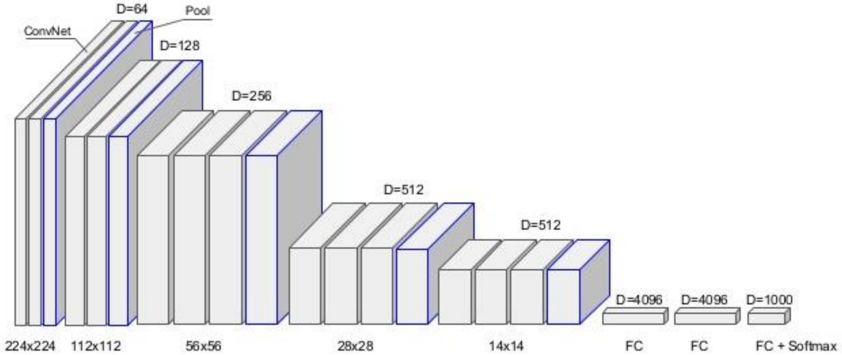
LeNet (1998)



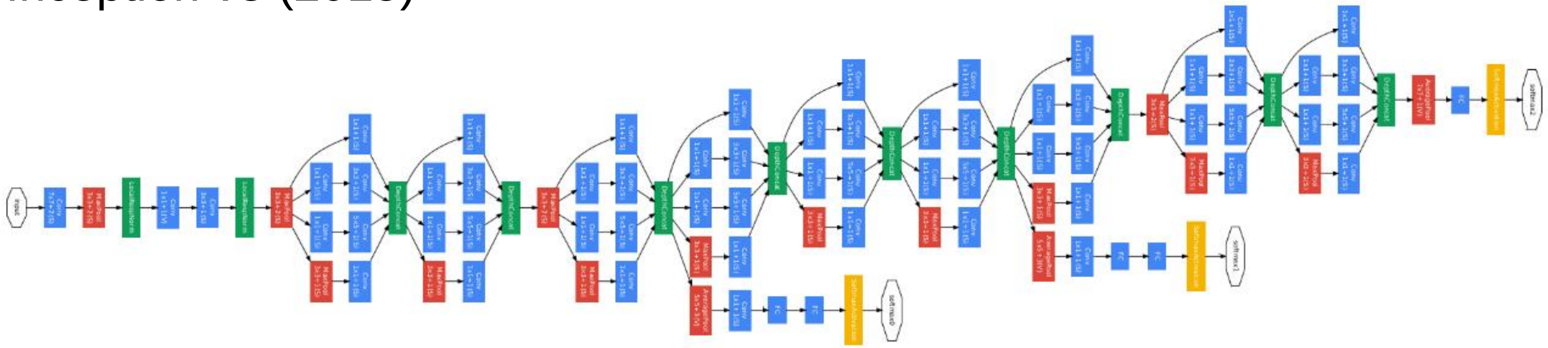
AlexNet (2012)



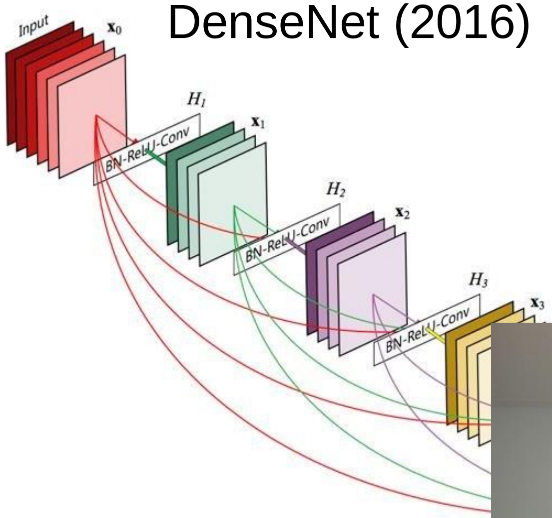
VGGNet (2013)



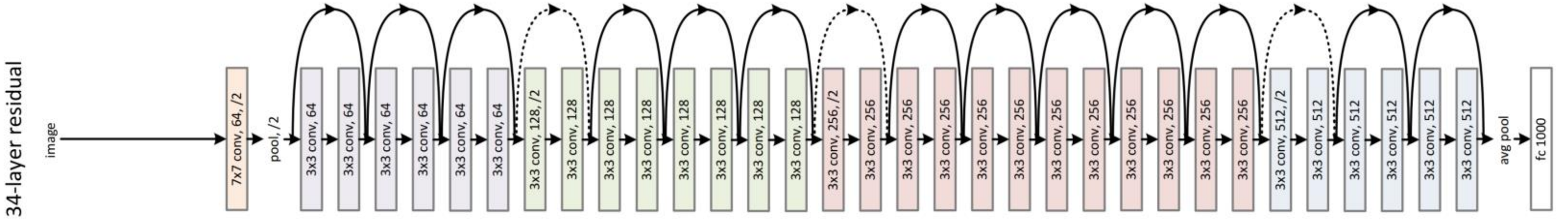
Inception v3 (2015)

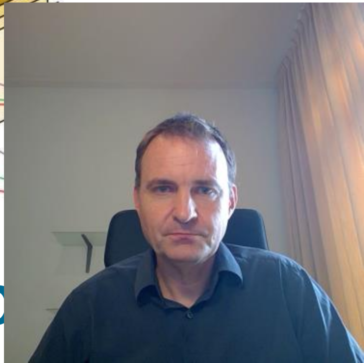


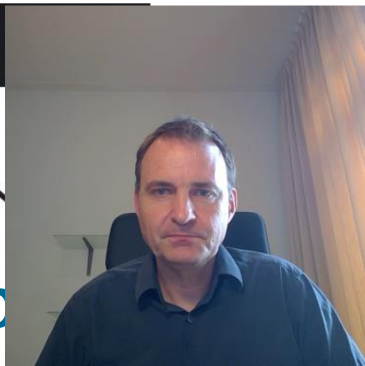
DenseNet (2016)



ResNet (2015)

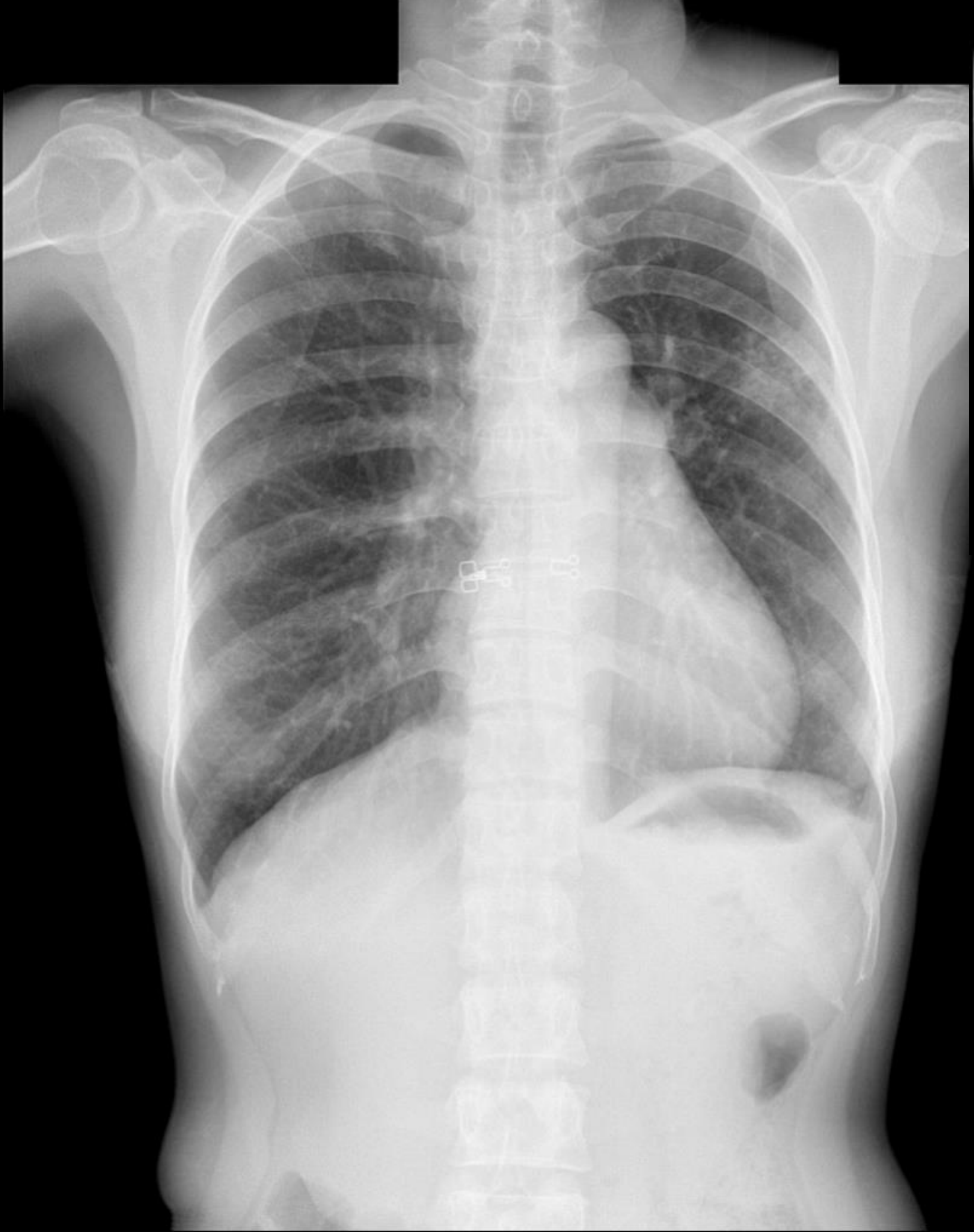


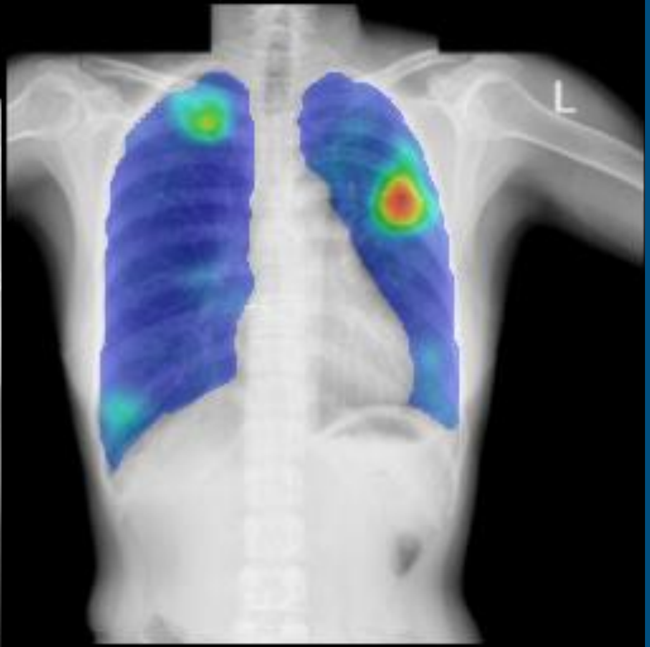




Stolen from https://twitter.com/curtlanglotz/status/1190143447291719682/photo/1

Radb





CAD4TB

Artificial intelligence for the detection of tuberculosis

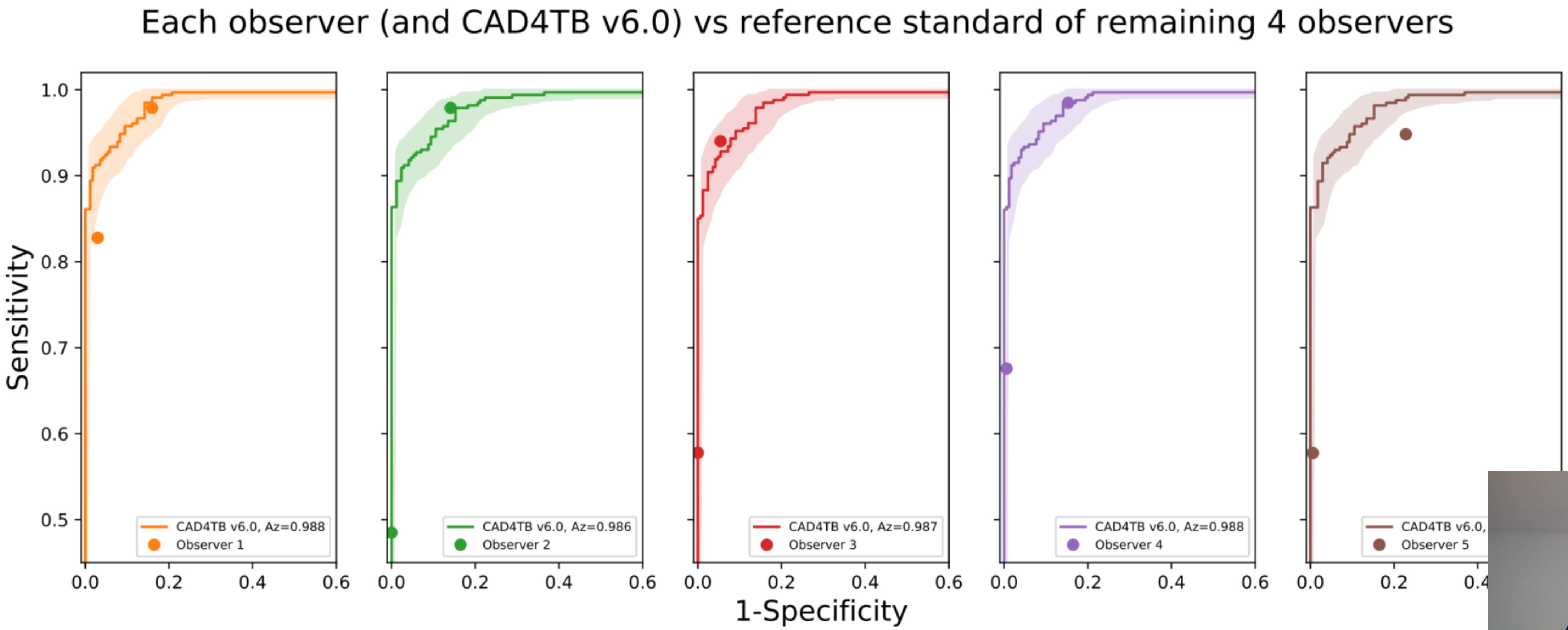
- CE certified
- 40+ publications
- Activated in 30+ countries
- Scree
  peopl

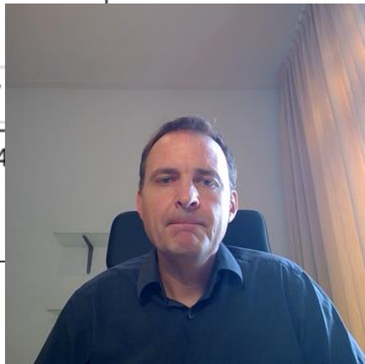

TB


TB

Computer aided detection of tuberculosis on chest radiographs: An evaluation of the CAD4TB v6 system

Keelin Murphy[1,*], Shifa Salman Habib[2], Syed Mohammad Asad Zaidi[2], Saira Khowaja[3,4], Aamir Khan[3,4], Jaime Melendez[5], Ernst T. Scholten[1], Farhan Amad[2], Steven Schalekamp[1], Maurits Verhagen[6], Rick H. H. M. Philipsen[5], Annet Meijers[5], and Bram van Ginneken[1]





Thoracic Imaging

Free Access

COVID-19 on the Chest Radiograph: A Multi-Reader Evaluation of an AI System

Keelin Murphy, Henk Smits, Arnoud J.G. Knoops, Mike B.J.M. Korst, Tijs Samson, Ernst T. Scholten, Steven Schalekamp, Cornelia M. Schaefer-Prokop, Rick H. H. M. Philipsen, Annet Meijers, Jaime Melendez, Bram van Ginneken, Matthieu Rutten

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- **Address correspondence to:** (email: keelin.murphy@radboudumc.nl)

Published Online: May 8 2020 | https://doi.org/10.1148/radiol.2020201874

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Recommended Articles

Augmenting the National Institutes of Health Chest Radiograph Dataset with Expert Annotations of Possible Pneumonia

Radiology: Artificial Intelligence, 2019
Volume: 1, Issue: 1

Deep Learning at Chest Radiography: Automated Classification of Pulmonary Tuberculosis by Using Convolutional Neural Networks

Radiology, 2017
Volume: 284, Issue: 2, pp. 574-582

Extension of Coronavirus Disease 2019 (COVID-19) on Chest CT and Implications for Chest Radiograph Interpretation

Radiology: Cardiothoracic Imaging, 2020
Volume: 2, Issue: 2

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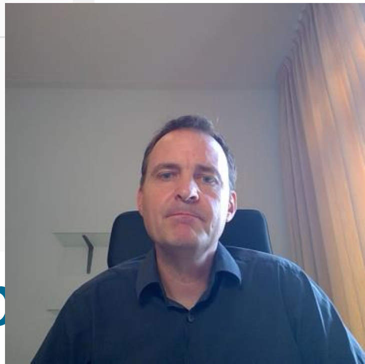
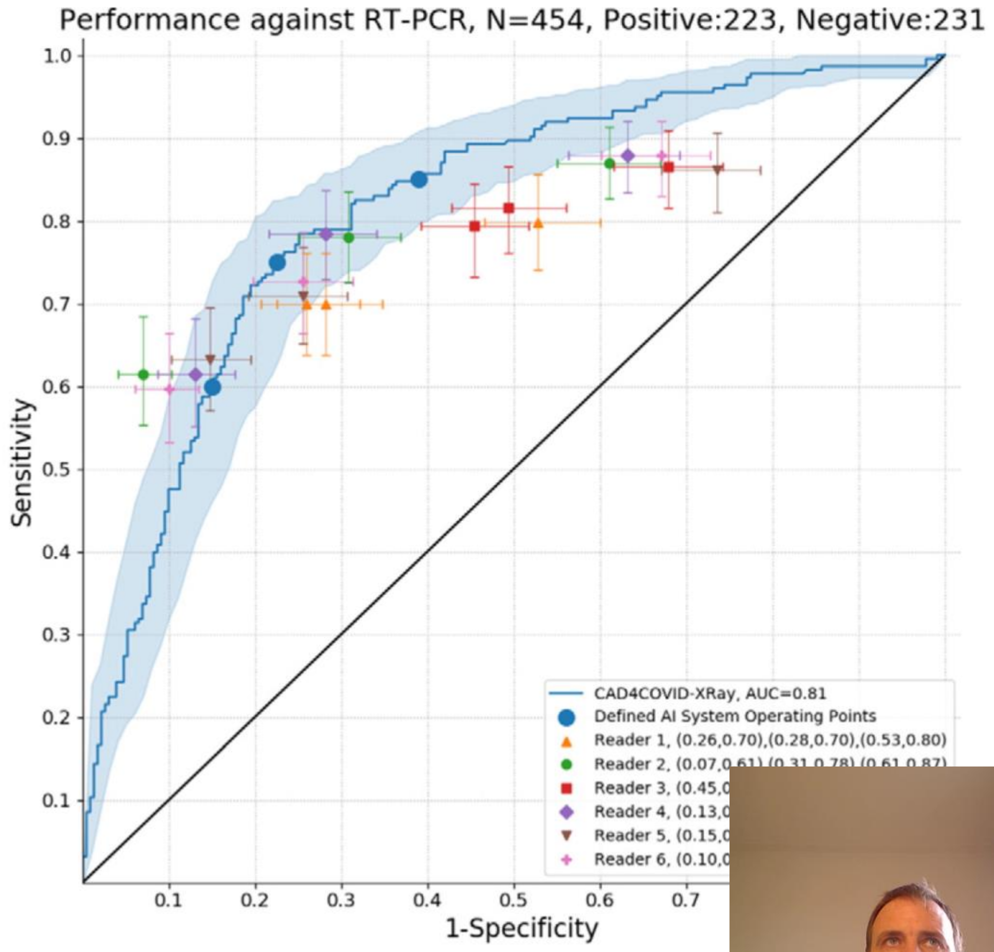
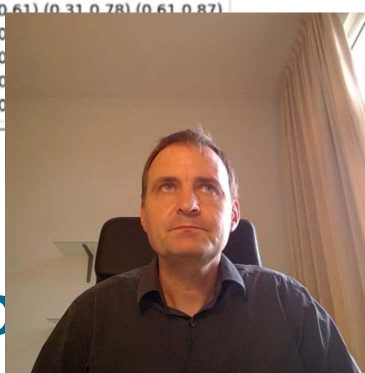


CAD4COVID-xray

- Started with pretrained CAD4TB
- Finetuned on pneumonia data
- Finetuned on COVID-19 x-rays from one Dutch hospital
- Test on data from a second Dutch hospital

- Observer study with 6 radiologists
- They scored each image as:
  - (0) Normal: No finding
  - (1) Abnormal but no lung opacity consistent with pneumonia
  - (2) Lung Opacity consistent with pneumonia (unlikely COVID-19)
  - (3) Lung Opacity consistent with pneumonia (consistent with COVID-19)





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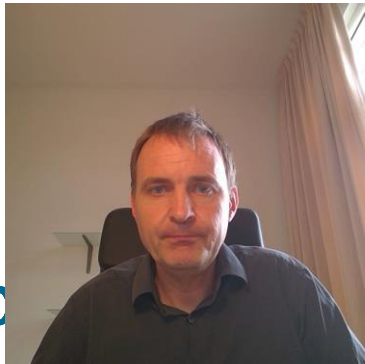
Fondation Botnar champions the use of AI and digital technology to improve the health and wellbeing of children and young people in growing urban environments around the world. We do this by supporting research, catalysing diverse partners, and investing in scalable solutions.

Radb



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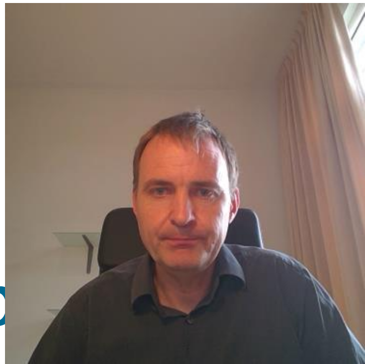


Infection prevention and control measures

Fever (history or >37.5°C) *or* Cough

no

yes

X-ray	**CAD4COVID**	**A**: High score
X-ray	**CAD4TB**	**B**: Above threshold
Pulse oximetry	**SpO_2**	**C**: ≤93%
RDT	**COVID-19**	**D**: positive

A or D

Presumptive COVID-19 case
non-severe

Self-quarantine or isolation depending on age and underlying conditions

A or D & C

Presumptive COVID-19 case
severe

Confirmatory COVID test and admission to specialised ward for care

A or D & B ± C

Presumptive COVID-19 and TB case

Confirmatory TB & COVID tests; transfer to infectious disease unit for care

B ± C

Presumptive TB case

Transfer to NTP, confirmatory TB test and management according to guidelines

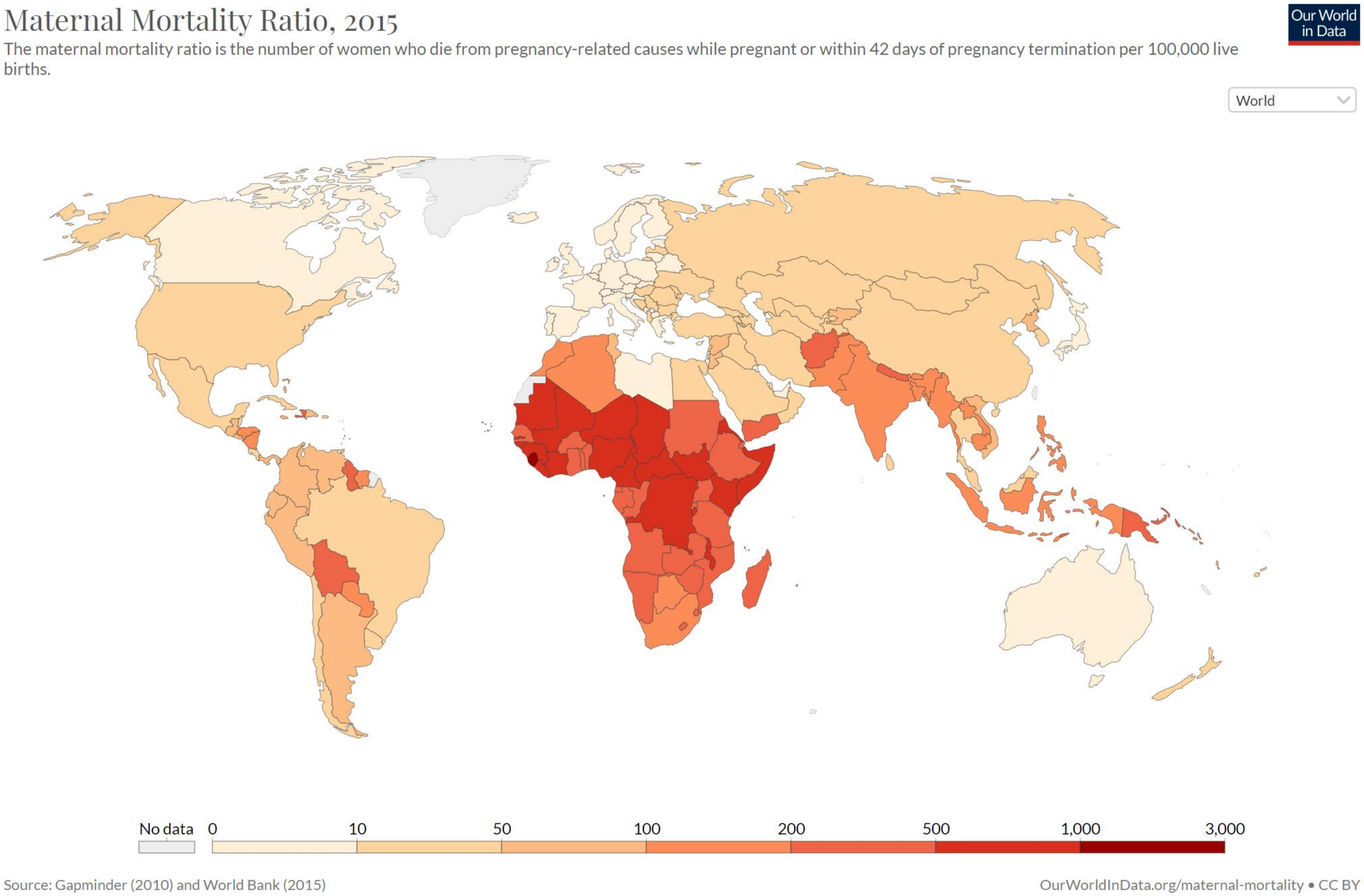
None

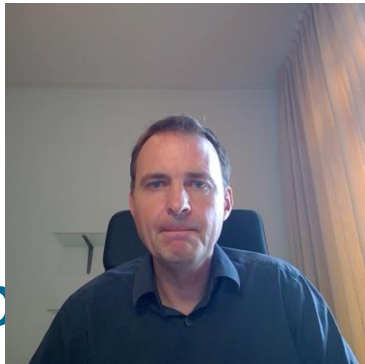
Other cause of illness

Consider F
febrile illne
transfer to

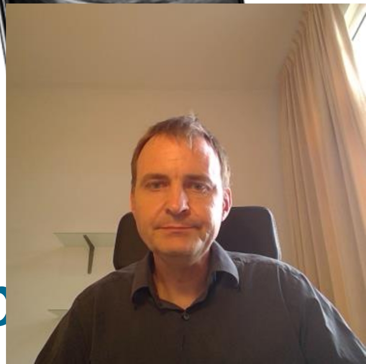
COVID-19 & TB triage algorithm for low-income countries with community transmission.
Klaus Reither, Swiss Tropical and Public Health Institute, Mistral Study funded by Botnar Foundation

800 maternal deaths per day, 99% in low resource countries





Low-cost ultrasound devices



Radb

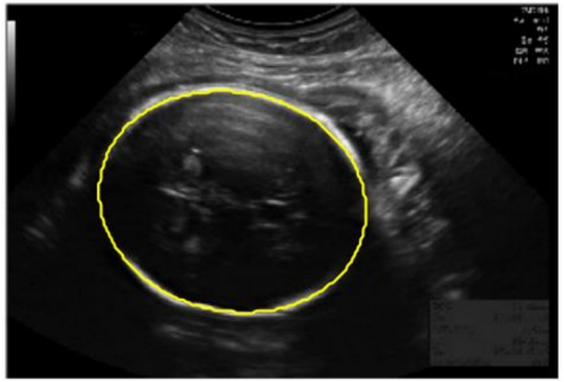
BabyChecker: current features

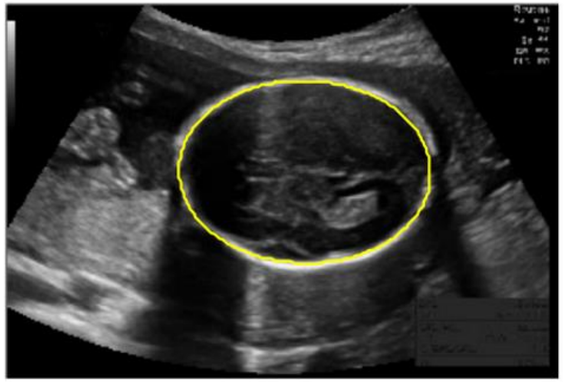
Gestational age

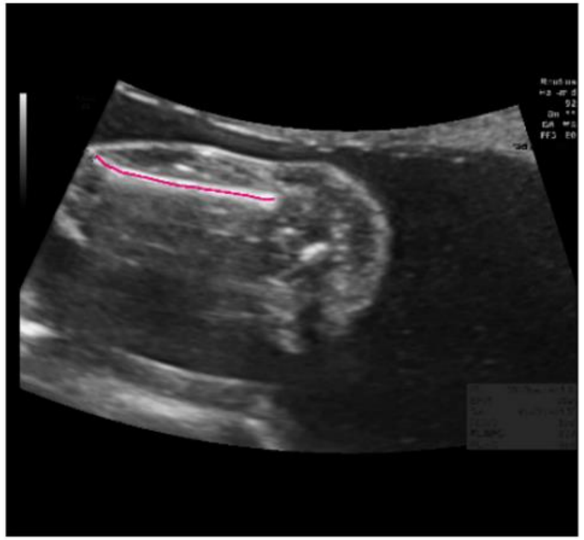
Twins

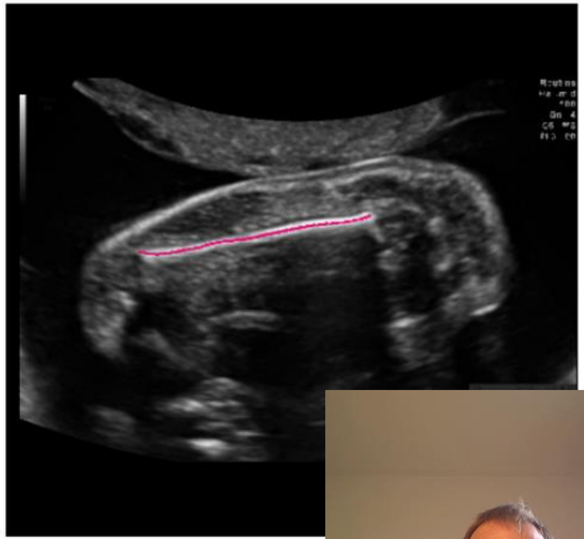
Breech position

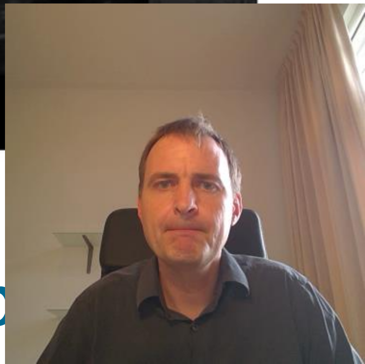
Automatic measurements are possible
But how to acquire the right frame?



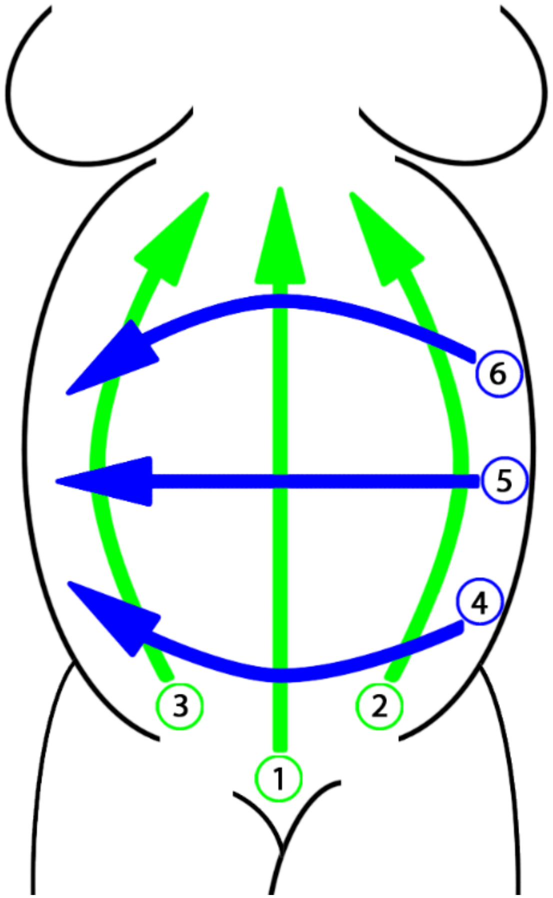


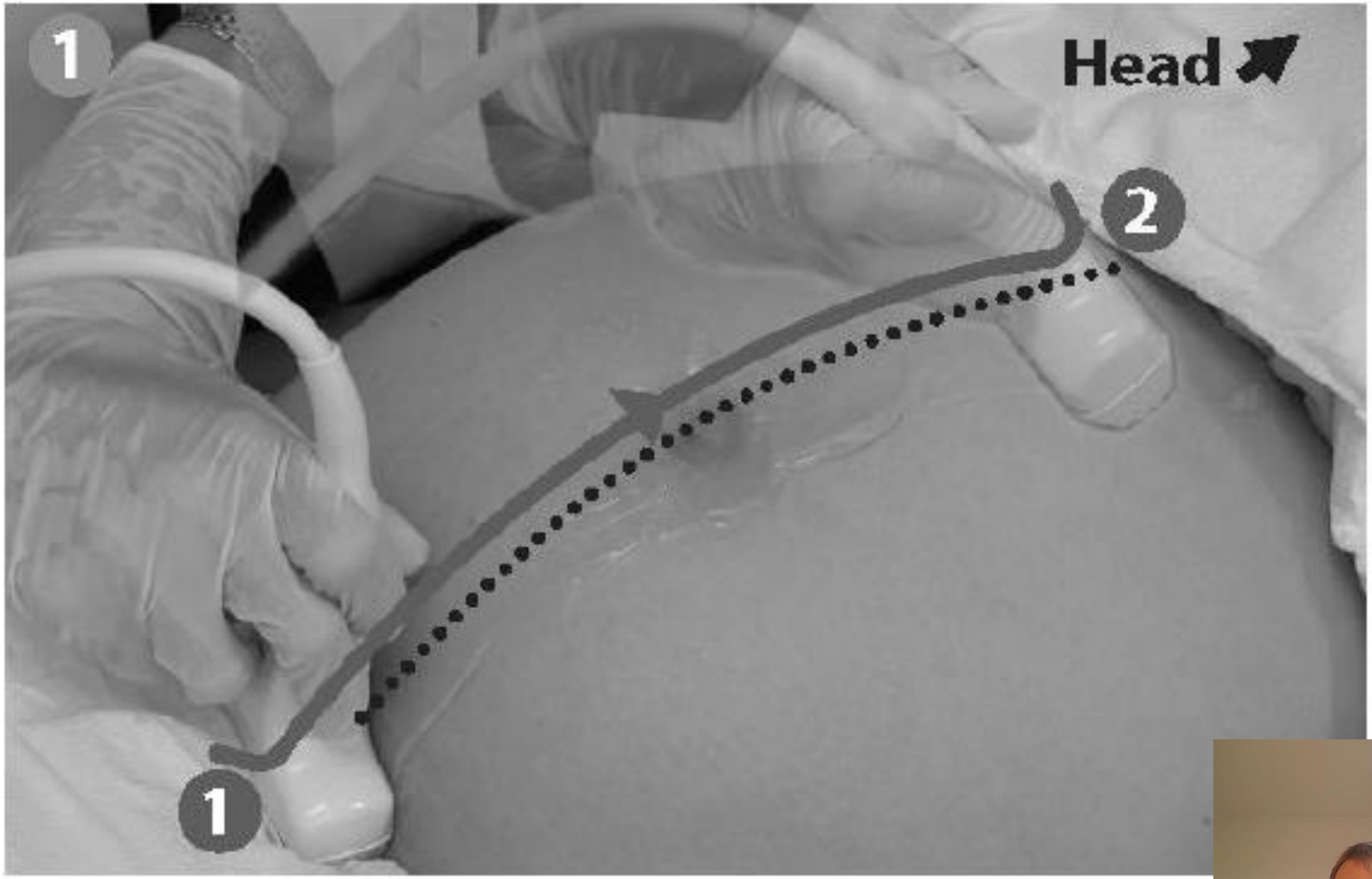




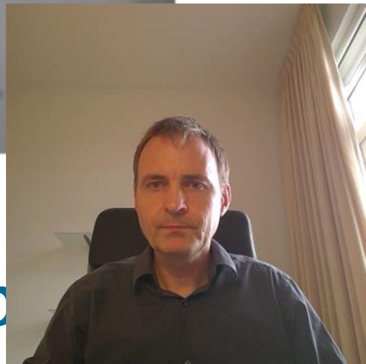


Sweep protocol





K.K. DeStigter *et al.*, Low-cost teleradiology for rural ultrasound, GHTC (2011)



Radb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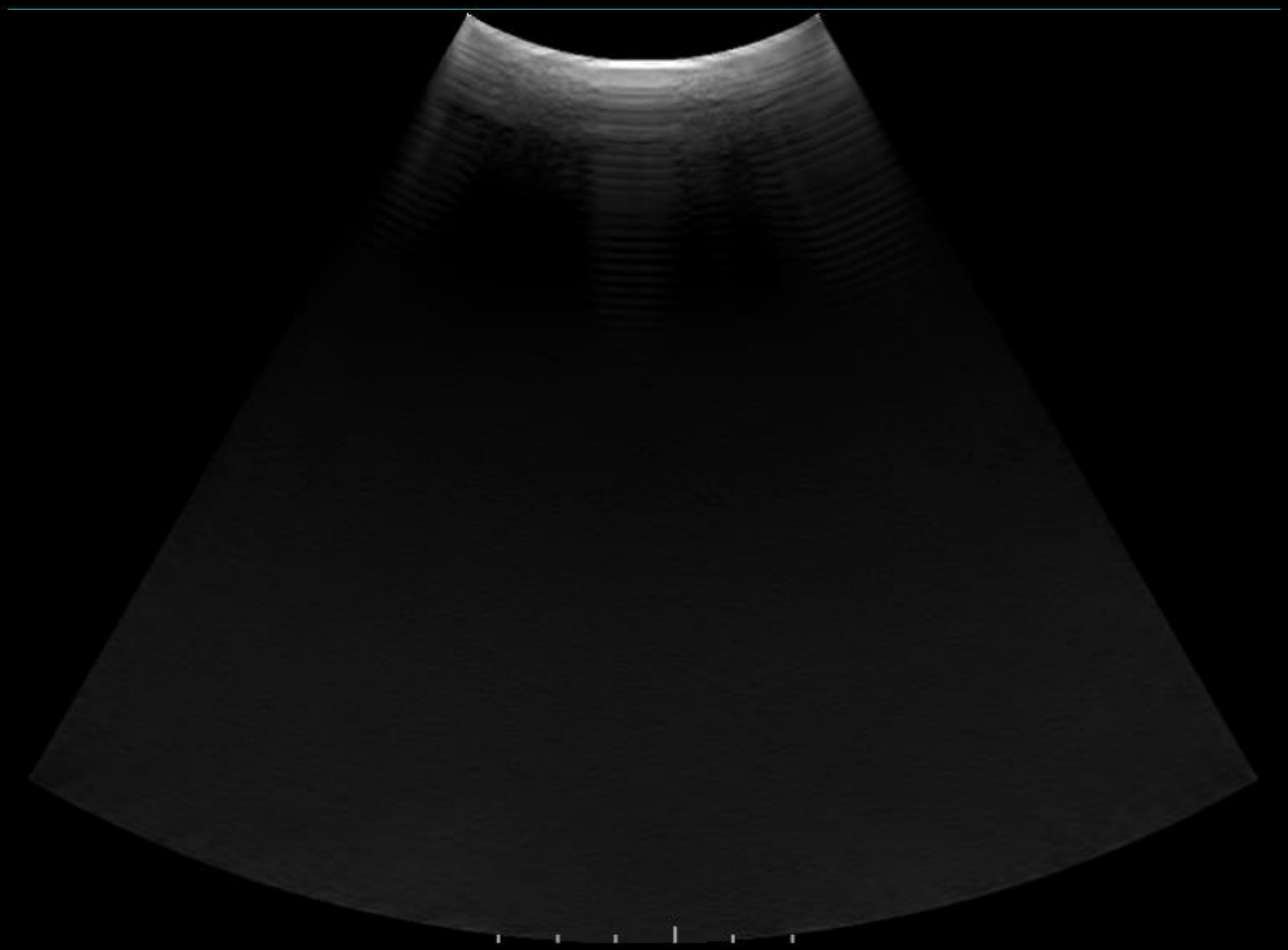


Head

Head partly

Body

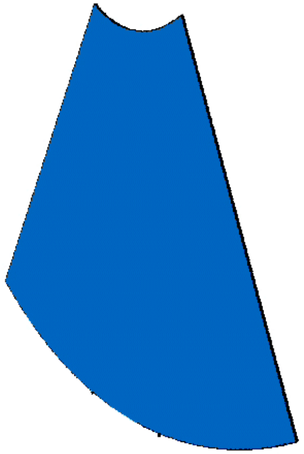
Side view

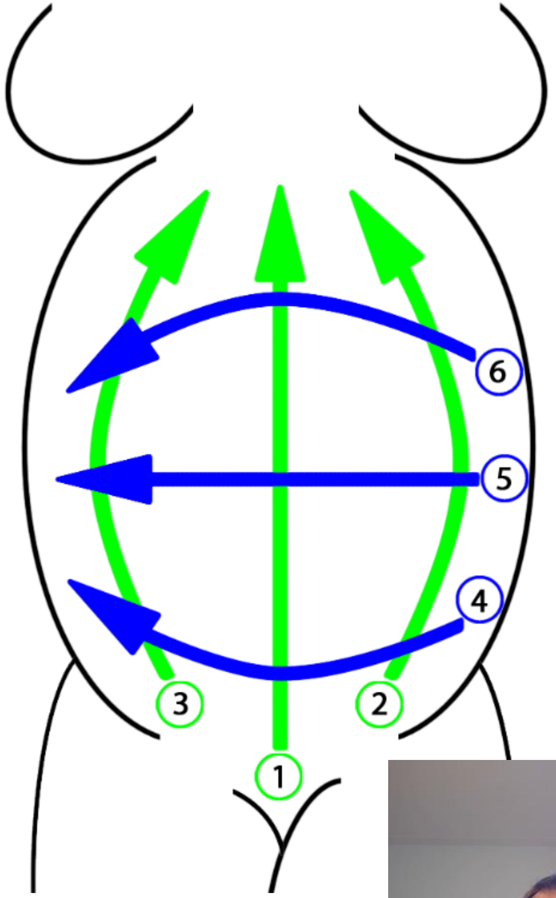
Transducer detached

Other

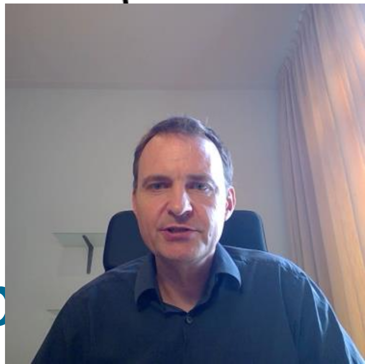
Sweep

- Head
- Head partly
- Body
- Side view
- Transducer detached
- Other



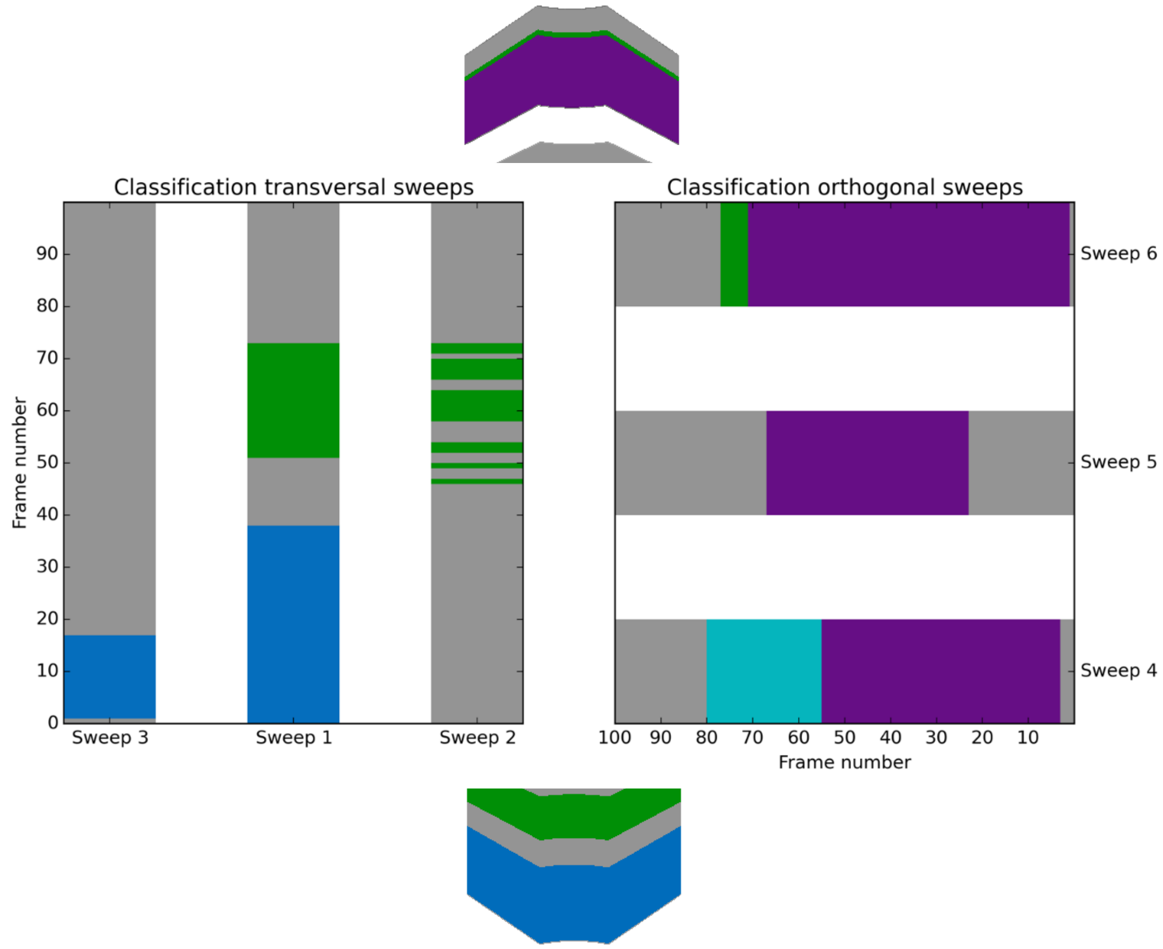


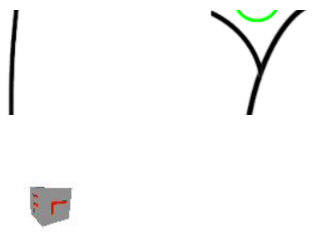
Radb

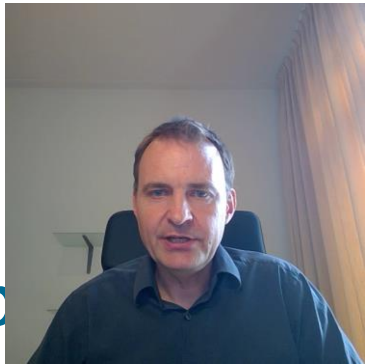


Automatic detection of pregnancy risks

- Head
- Head partly
- Body
- Sideview
- Transducer detached
- Other

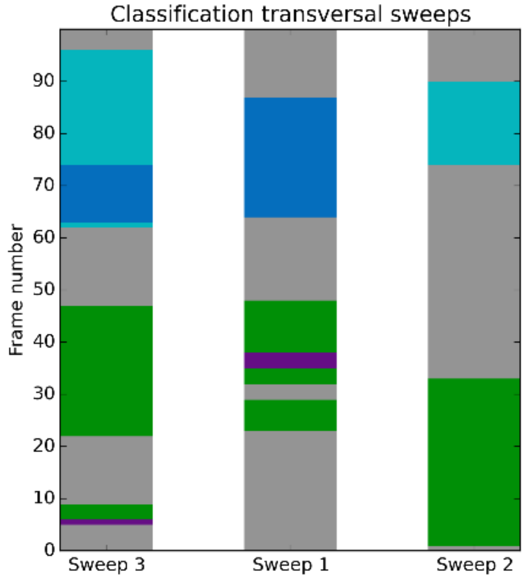


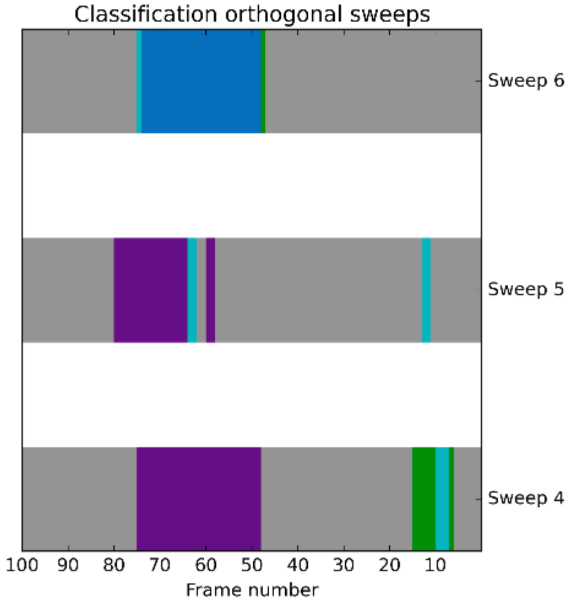


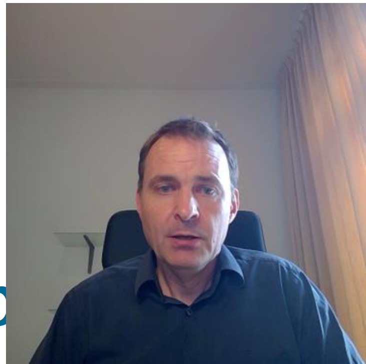


Automatic detection of pregnancy risks

- Head
- Head partly
- Body
- Sideview
- Transducer detached
- Other

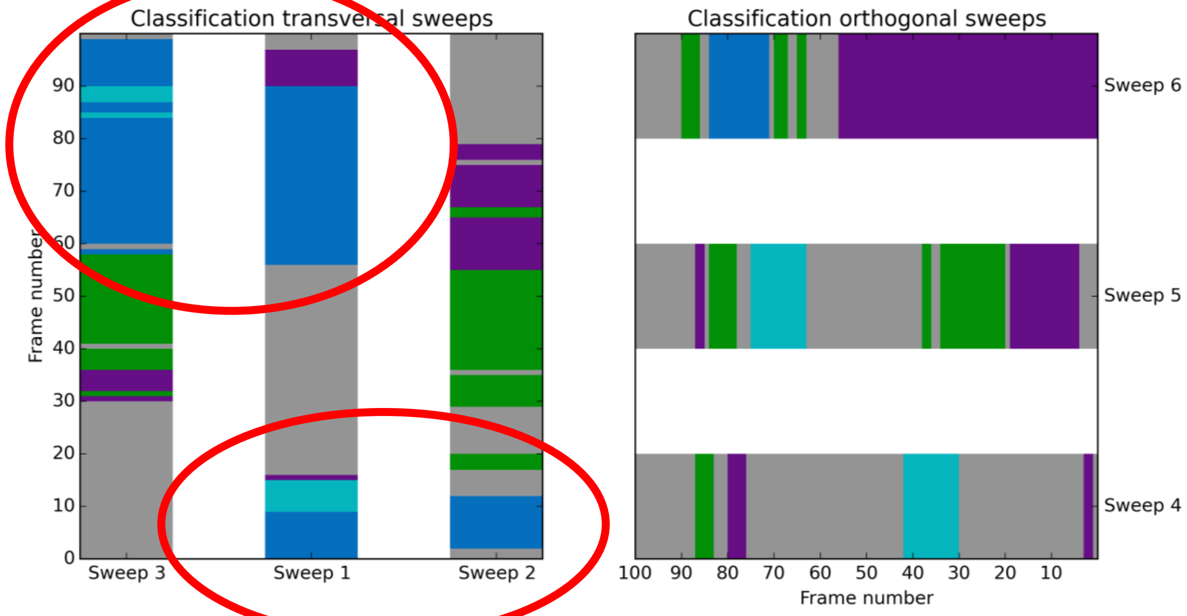


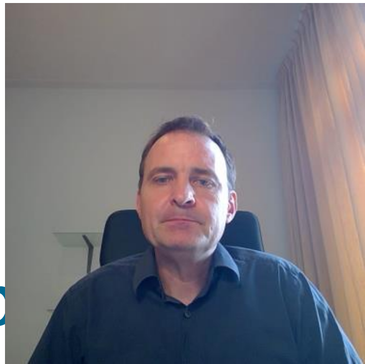




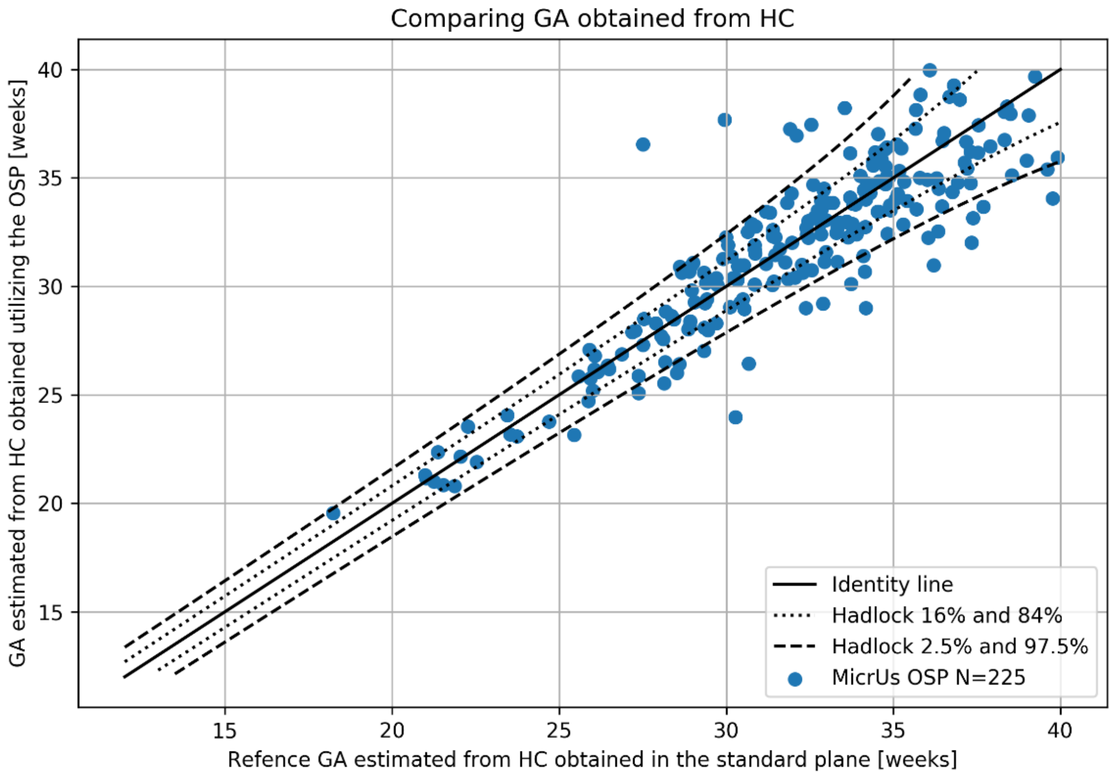
Automatic detection of pregnancy risks

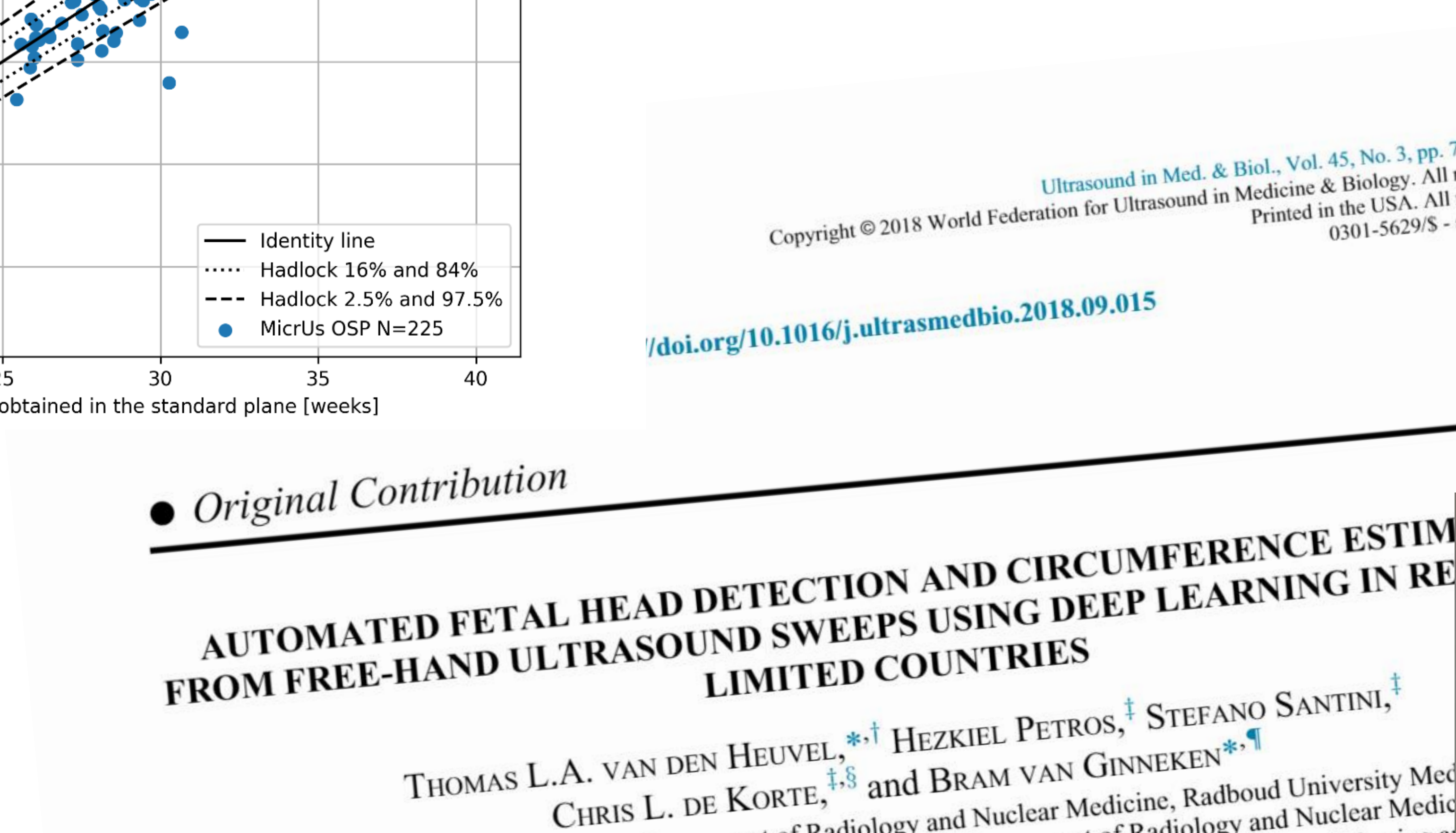
- Head
- Head partly
- Body
- Sideview
- Transducer detached
- Other





Estimation of gestational age from sweep frames





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/doi.org/10.1016/j.ultrasmedbio.2018.09.015

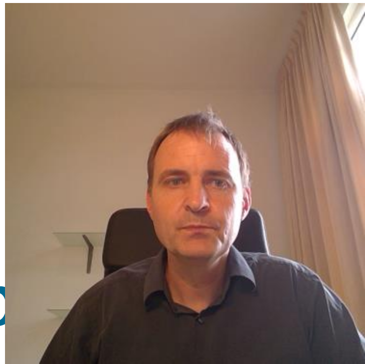
● *Original Contribution*

AUTOMATED FETAL HEAD DETECTION AND CIRCUMFERENCE ESTIM
FROM FREE-HAND ULTRASOUND SWEEPS USING DEEP LEARNING IN RE
LIMITED COUNTRIES

THOMAS L.A. VAN DEN HEUVEL,[*,†] HEZKIEL PETROS,[‡] STEFANO SANTINI,[‡]
CHRIS L. DE KORTE,[‡,§] and BRAM VAN GINNEKEN[*,¶]

Current status of the BabyChecker

- All deep learning networks running real-time on Android phone
- Real-time feedback during acquisition of the sweeps
- Segmentation of placenta for detection of placenta previa
- Investigating adjustment of the sweep protocol
- Planned release 2021



Two examples of low-cost healthcare solutions

- Countries with limited resources are open to use of AI

- Deep learning made rapid development of these applications possible
  - They do not run on an expensive GPU
  - They do not require millions of example images