Lung Disease and AI applications:
From cough sounds to CAT scans

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The COVID19 pandemic was a testing time for AI

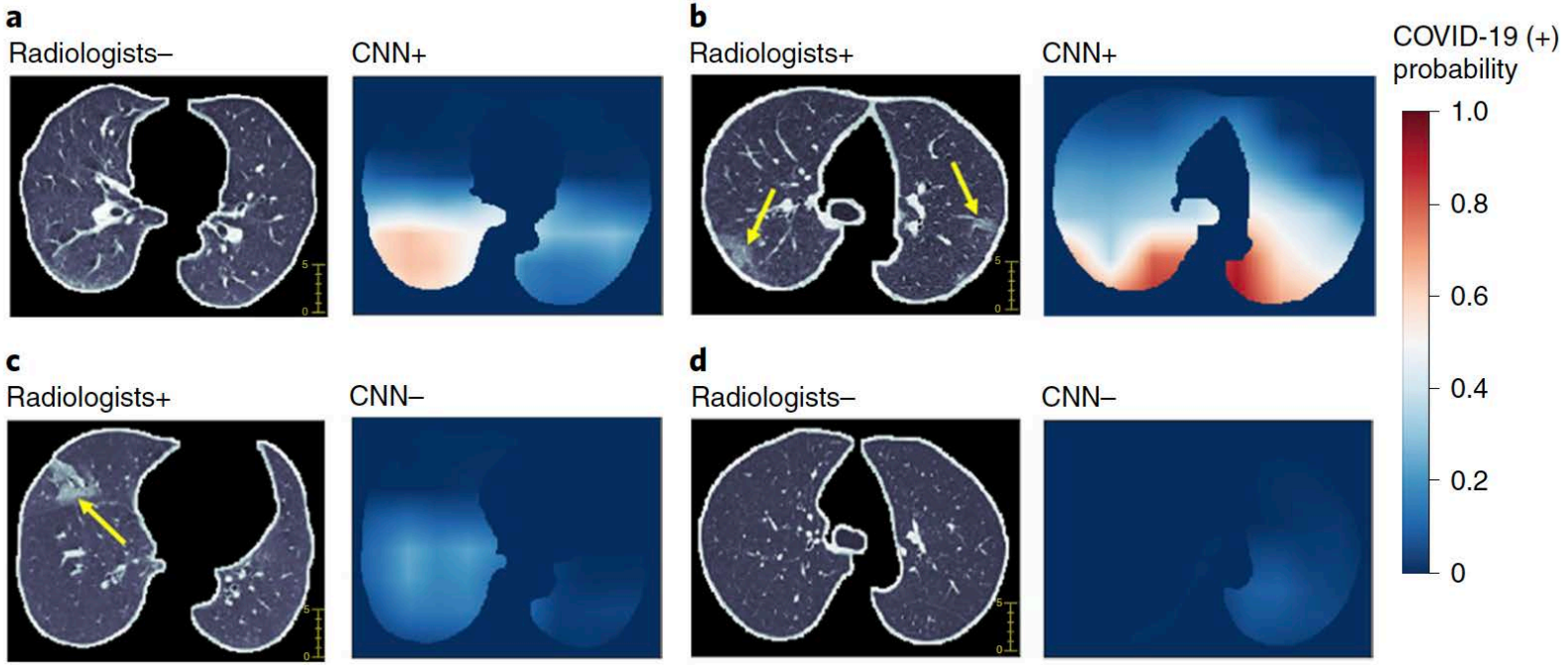
AI enabled CT Scan as a primary diagnostic modality for COVID19

LETTERS
https://doi.org/10.1038/s41591-020-0931-3
nature medicine
Check for updates

Artificial intelligence–enabled rapid diagnosis of patients with COVID-19

Xueyan Mei[1,16], Hao-Chih Lee[2,16], Kai-yue Diao[3,16], Mingqian Huang[4], Bin Lin[5], Chenyu Liu[1], Zongyu Xie[6], Yixuan Ma[1], Philip M. Robson[1,4], Michael Chung[4], Adam Bernheim[4], Venkatesh Mani[1,4], Claudia Calcagno[1,4], Kunwei Li[7], Shaolin Li[7], Hong Shan[7], Jian Lv[8], Tongtong Zhao[9], Junli Xia[10], Qihua Long[11], Sharon Steinberger[4], Adam Jacobi[4], Timothy Deyer[12,13], Marta Luksza[14], Fang Liu[15], Brent P. Little[15,17] ✉, Zahi A. Fayad[1,4,17] ✉ and Yang Yang[1,4,17] ✉

- In early 2020, it was easier for China to do large scale CT scans with automated analysis to diagnose and triage patients (Mei et al August 2020, Nature Med) than to rely only on molecular testing
- Outperformed junior rads
- PCR-ve cases as well



Yet, there were big failures as well

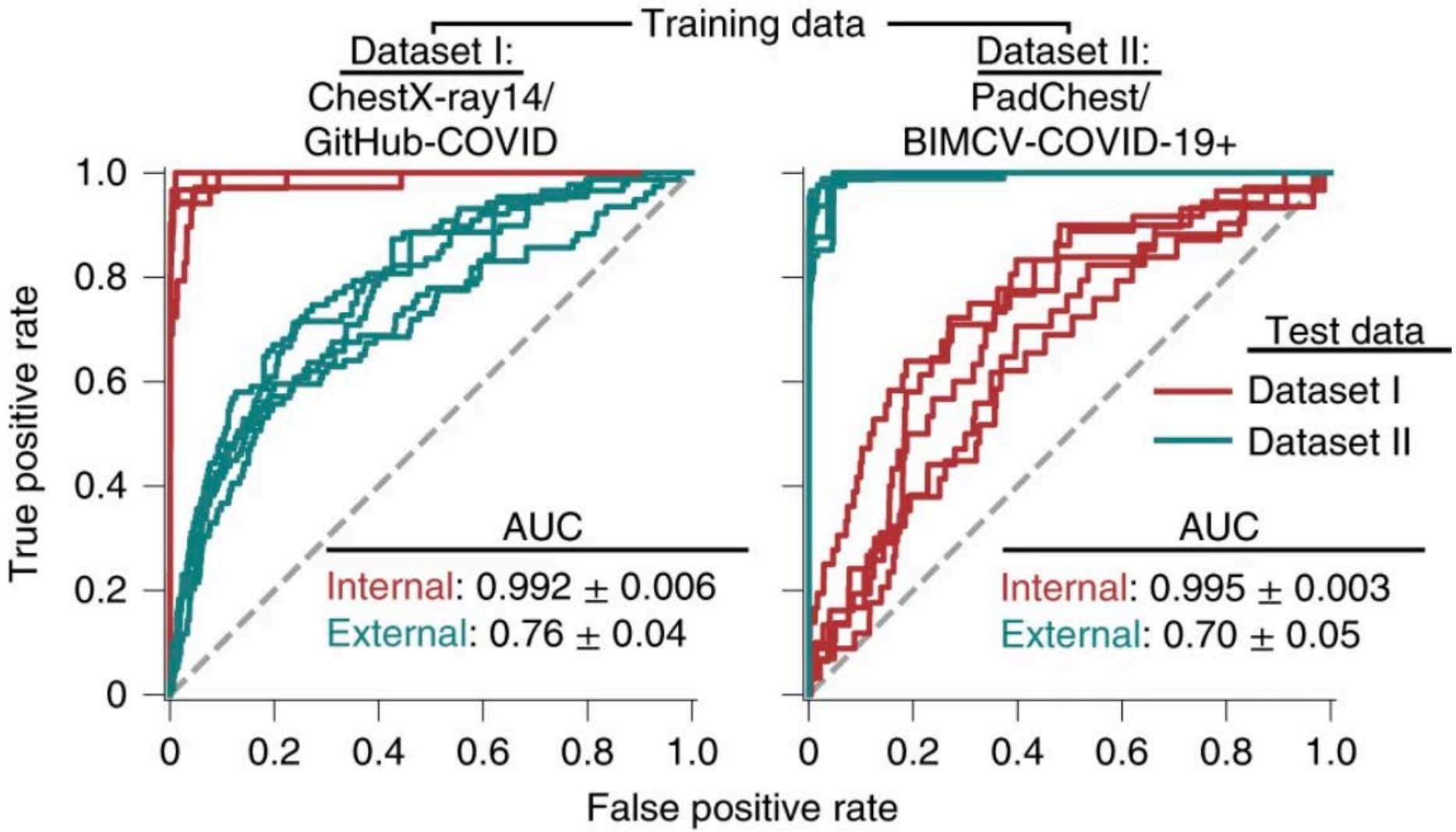
ARTICLES
https://doi.org/10.1038/s42256-021-00338-7
nature machine intelligence

Check for updates

AI for radiographic COVID-19 detection selects shortcuts over signal

Alex J. DeGrave[1,2,3], Joseph D. Janizek[1,2,3] and Su-In Lee[1]✉

Artificial intelligence (AI) researchers and radiologists have recently reported AI systems that accurately detect COVID-19 in chest radiographs. However, the robustness of these systems remains unclear. Using state-of-the-art techniques in explainable AI, we demonstrate that recent deep learning systems to detect COVID-19 from chest radiographs rely on confounding factors rather than medical pathology, creating an alarming situation in which the systems appear accurate, but fail when tested in new hospitals. We observe that the approach to obtain training data for these AI systems introduces a nearly ideal scenario for AI to learn these spurious 'shortcuts'. Because this approach to data collection has also been used to obtain training data for the detection of COVID-19 in computed tomography scans and for medical imaging tasks related to other diseases, our study reveals a far-reaching problem in medical-imaging AI. In addition, we show that evaluation of a model on external data is insufficient to ensure AI systems rely on medically relevant pathology, because the undesired 'shortcuts' learned by AI systems may not impair performance in new hospitals. These findings demonstrate that explainable AI should be seen as a prerequisite to clinical deployment of machine-learning healthcare models.


Training data
Dataset I:
ChestX-ray14/
GitHub-COVID
Dataset II:
PadChest/
BIMCV-COVID-19+
True positive rate
False positive rate
1.0
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1.0
AUC
Internal: 0.992 ± 0.006
External: 0.76 ± 0.04
AUC
Internal: 0.995 ± 0.003
External: 0.70 ± 0.05
Test data
Dataset I
Dataset II

Types of data

- Text
  - ***Symptoms***
  - Prior medical history and signs
- Sounds
  - ***Breath sounds***
  - ***Cough***
  - Speech
- Physiologic
  - ***Vitals including O2 saturation***
  - ***Spirometry***
  - ***Oscillometry***
  - *Ventilator data*
  - ***Sleep studies***
- Images / Videos
  - Chest
  - ***Fingers (clubbing)***
  - ***X Rays / CT***
  - Microscopy
  - CT / CT Angiography
  - Perfusion scans
  - Bronchoscopy
- Biochemical and -omic
  - Blood, pleural fluid, exhaled breath condensate, broncho-alveolar fluid
  - ***eNose***

Hi, I’m Ada.
I can help if you’re feeling unwell.

UK

“Brilliant - the app reported my son could have scarlet fever and it turns out he does have exactly that. Great app will use again.”

★★★★★

Australia

“Recommend!!! This is one of the best apps of all time it is so helpful!”

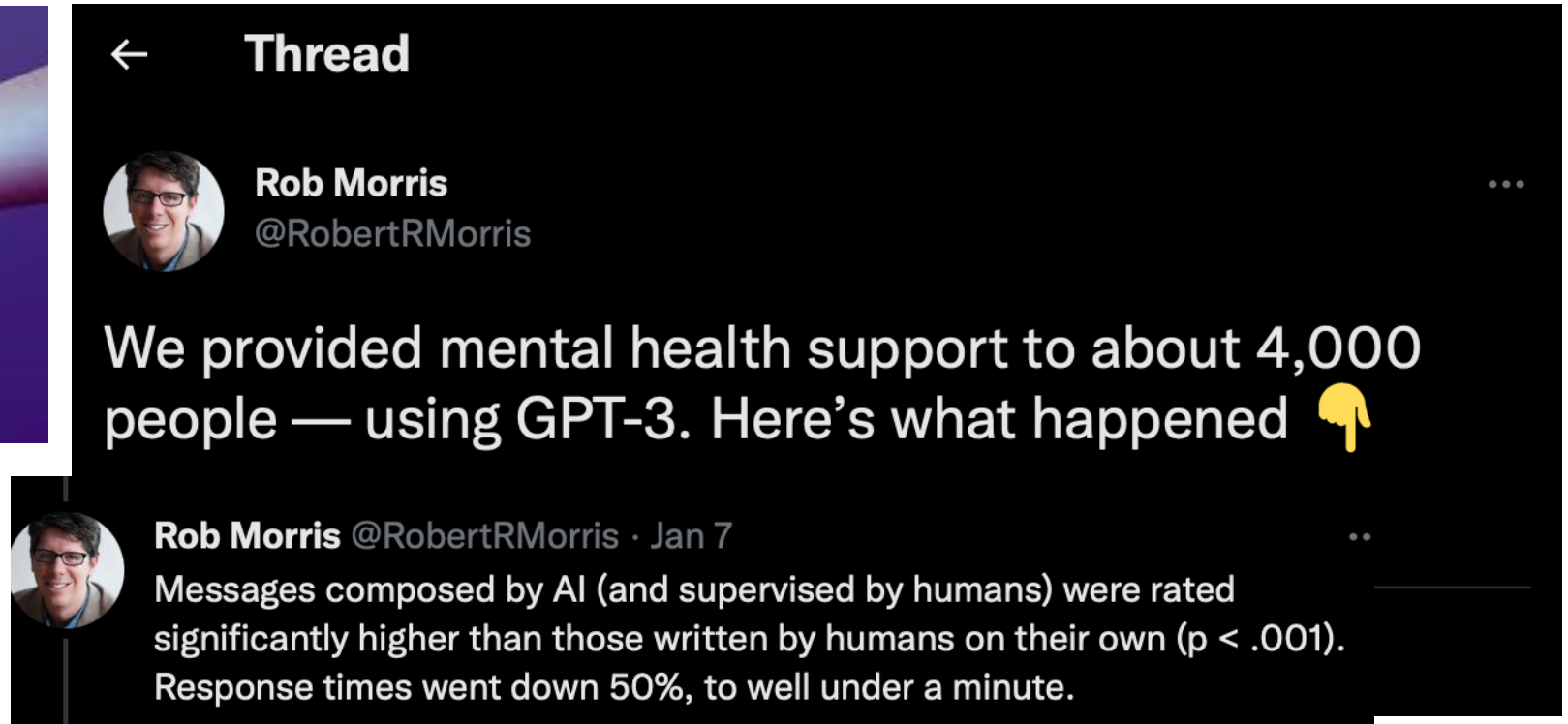
★★★★★

USA

“This app actually helped my doctor know what's wrong with my shoulder. So grateful for it!”

★★★★★

Generative AI will change human-computer interactions



Complexity is not a problem, Hallucination is

Research Letter

ONLINE FIRST

June 15, 2023

Accuracy of a Generative Artificial Intelligence Model in a Complex Diagnostic Challenge

Zahir Kanjee, MD, MPH[1]; Byron Crowe, MD[1]; Adam Rodman, MD, MPH[1]

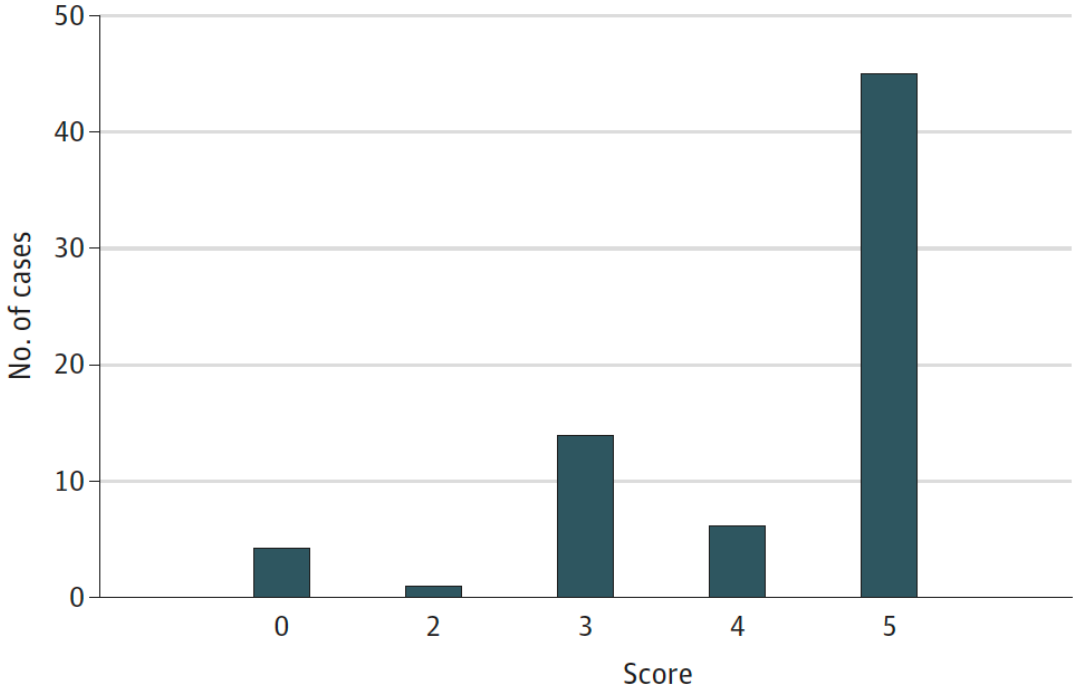
» Author Affiliations | Article Information

JAMA. Published online June 15, 2023. doi:10.1001/jama.2023.8288

Tested in NEJM CPC cases Jan 2021- Dec 22

- Correct diagnosis in its differential in 64% of challenging cases
- Its top diagnosis in 39%.

Figure. Performance of Generative Pre-trained Transformer 4 (GPT-4)



Histogram of GPT-4's performance. Performance scale scores (Bond et al[2]): 5 = the actual diagnosis was suggested in the differential; 4 = the suggestions included something very close, but not exact; 3 = the suggestions included something closely related that might have been helpful; 2 = the suggestions included something related, but unlikely to be helpful; 0 = no suggestions close to the target diagnosis. (The scale does not contain a score of 1.)

Foundational AI is next

Gyan
From Search to Knowledge

First Explainable Language Model Based Natural Language Processing Engine

SCIENCE

ChatGPT appears to pass medical school exams. Educators are now rethinking assessments

ABC Science / By technology reporter James Purtill

Posted Thu 12 Jan 2023 at 12:30am

Researchers just tested ChatGPT on the same test questions as aspiring doctors — and found the AI was 'comfortably within the passing range'

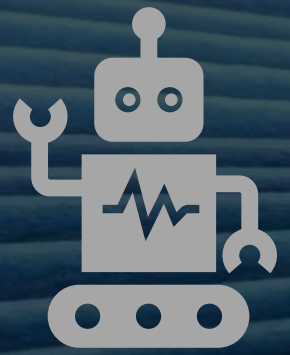
Performance of ChatGPT on USMLE: Potential for AI-Assisted Medical Education Using Large Language Models

Tiffany H. Kung, Morgan Cheatham, ChatGPT, Arielle Medenilla, Czarina Sillos, Lorie De Leon, Camille Elepaño, Maria Madriaga, Rimel Aggabao, Giezel Diaz-Candido, James Maningo, Victor Tseng

doi: https://doi.org/10.1101/2022.12.19.22283643

Diagnosis in the age of LLMs / Generative AI

Convert the problems of a physical patient into accurate digital inputs / prompts, with minimal requirement of expert practitioners



Blended workflows leveraging the strength (minimizing the weaknesses) of different AI systems

I. Listening isn't just about the symptoms

Kevat *et al. Respiratory Research* (2020) 21:253
https://doi.org/10.1186/s12931-020-01523-9

Respiratory Research

RESEARCH Open Access

Artificial intelligence accuracy in detecting pathological breath sounds in children using digital stethoscopes

Ajay Kevat[1,2*], Anaath Kalirajah[1] and Robert Roseby[1,2]

Breath sounds and why they matter

- Wheeze
  - Monophonic
  - Polyphonic
  - Inspiratory / Expiratory
    - early/ mid / late
- Crackle
  - Fine
  - Coarse
  - Inspiratory / Expiratory
    - early/ mid / late

WHEEZE
a rapid periodic sinusoidal waveform of total length > 25 msec with a dominant frequency > 100 Hz

CRACKLE
a short initial soundwave deflection from a baseline followed by a longer, dampening sinusoidal wave with < 20 msec two-cycle duration and < 25 msec total duration width

II. Cough: More than just a sound

scientific reports

OPEN

Development and clinical validation of Swaasa AI platform for screening and prioritization of pulmonary TB

Gayatri Devi Yellapu[1], Gowrisree Rudraraju[2]✉, Narayana Rao Sripada[2], Baswaraj Mamidgi[2], Charan Jalukuru[2], Priyanka Firmal[2], Venkat Yechuri[2], Sowmya Varanasi[1], Venkata Sudhakar Peddireddi[1], Devi Madhavi Bhimarasetty[1], Sidharth Kanisetti[1], Niranjan Joshi[3],

scientific reports

OPEN

A novel automatic cough frequency monitoring system combining a triaxial accelerometer and a stretchable strain sensor

Takehiro Otoshi[1], Tatsuya Nagano[1]✉, Shintaro Izumi[2], Daisuke Hazama[1], Naoko Katsurada[1], Masatsugu Yamamoto[1], Motoko Tachihara[1], Kazuyuki Kobayashi[1] & Yoshihiro Nishimura[1]

npj | Digital Medicine

www.nature.com/npjdigitalmed

ARTICLE OPEN

Identifying acute exacerbations of chronic obstructive pulmonary disease using patient-reported symptoms and cough feature analysis

Scott Claxton[1,2], Paul Porter[1,3,4]✉, Joanna Brisbane[1,4], Natasha Bear[5], Javan Wood[6], Vesa Peltonen[6], Phillip Della[3], Claire Smith[1,4] and Udantha Abeyratne[6,7]

Swaasa AI

- 80 % training, 20% validating, and final external testing phases

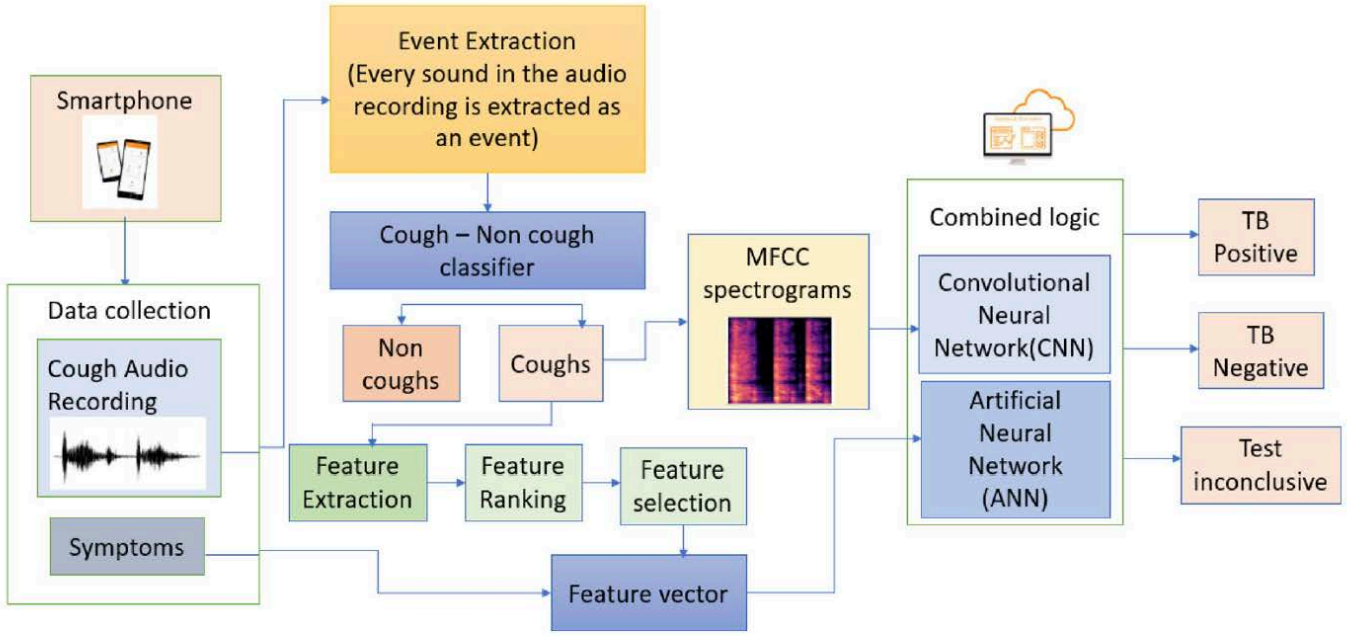
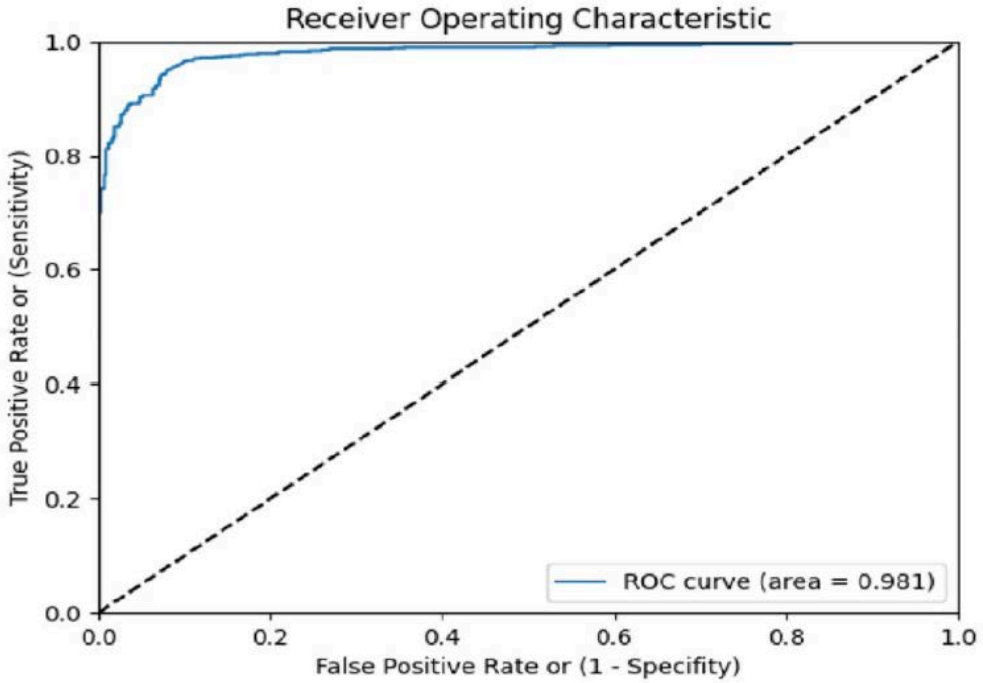
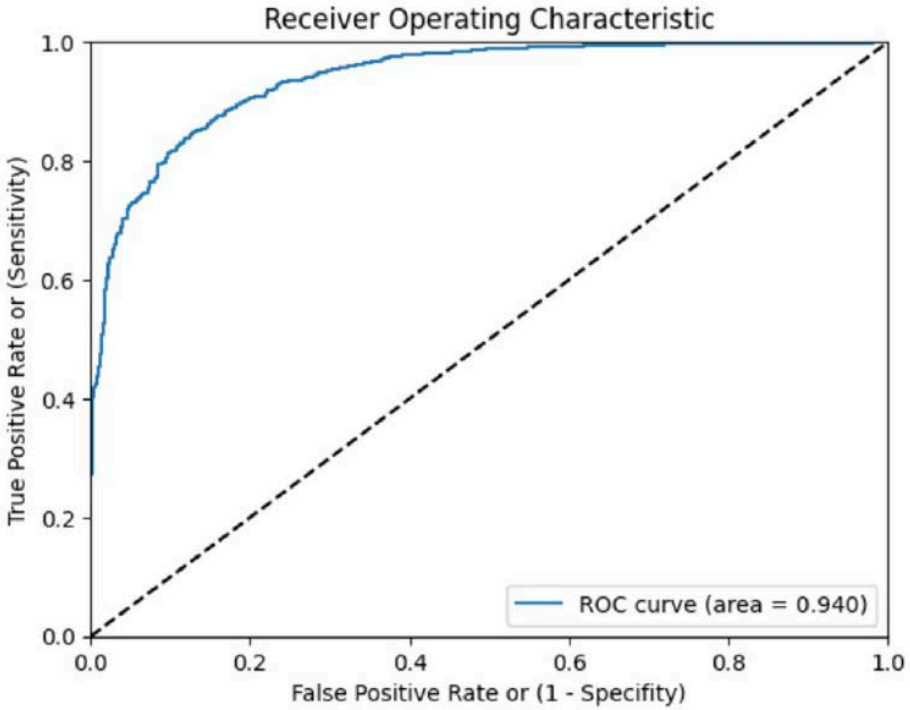


Figure 3. Block Diagram illustrating the flow of the TB prediction model.

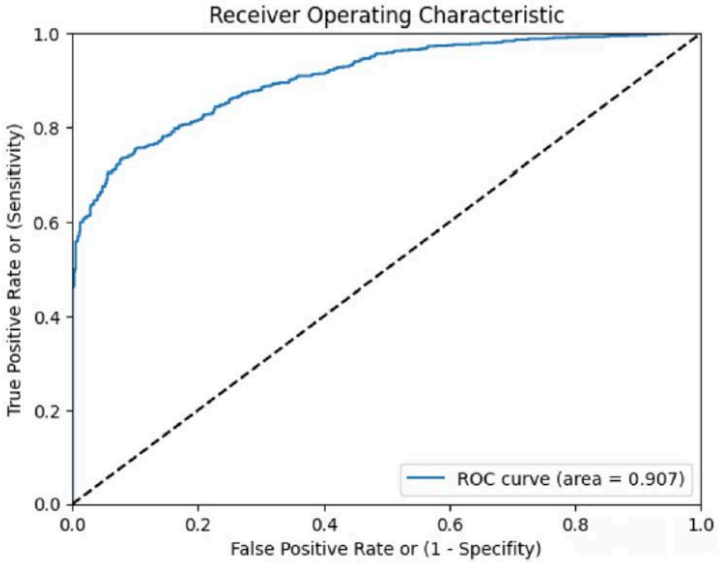
Disease	Cough signature	Spectrogram	LIME maps
PTB			
Asthma			
Normal			
ILD			
Pneumonia			



Initial Training



Retraining after validation



Pilot clinical study

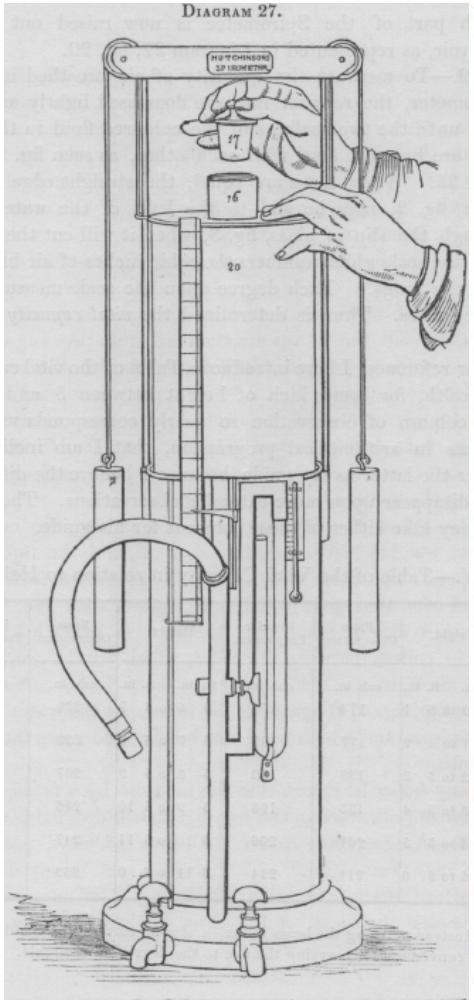
	TB likely—Yes	TB likely—No
TB—Yes	15 (TP)	9 (FN)
TB—No	5 (FP)	36 (TN)

III. Prognosis is often best measured through physiological tests

- Spirometry
- Oscillometry
- Plethysmography
- Walk tests
- Exercise tests

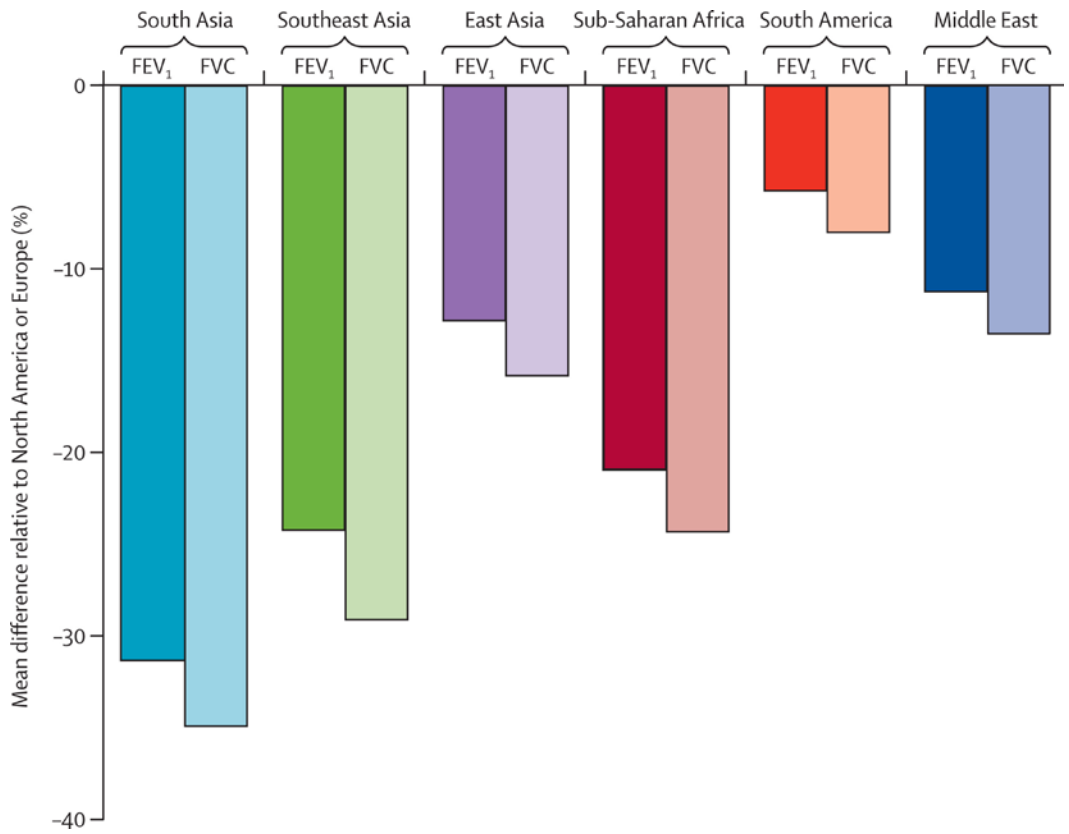
Vital Capacity: A measure of vitality

- John Hutchison
  - Spirometer, 1846
  - How much air can be forcefully exhaled after a maximum inhalation (Vital Capacity)
  - Inverted Bell floating on water



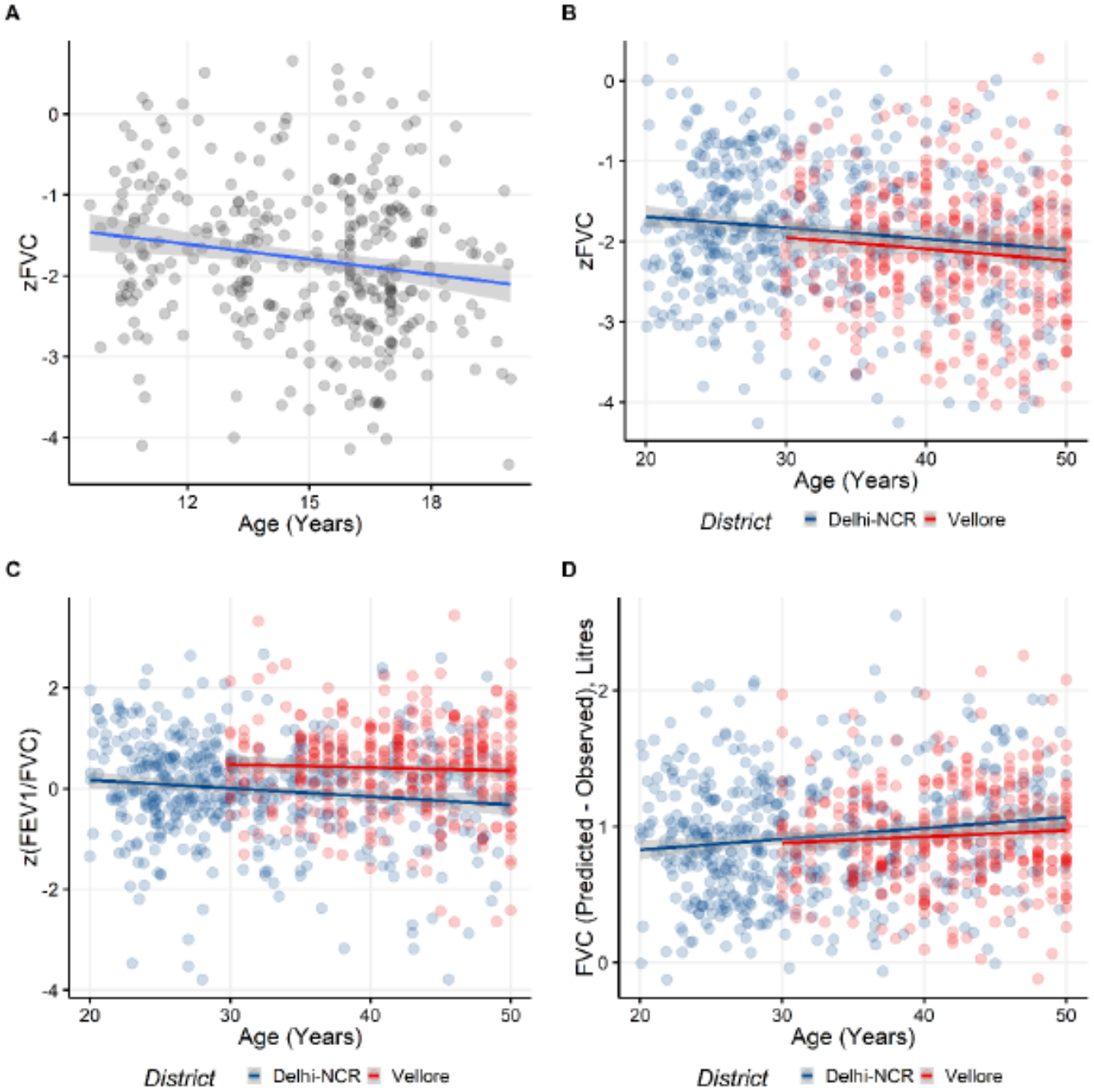
PURE-BREATH study

- Spirometry from 38,517 subjects across 17 countries
- South Asians had about a third lower lung volumes than Caucasians
- Duong et al Lancet Respiratory Medicine 2013



Worse with age

- In over 1000 subjects from NCR and Vellore, age related decline in relative FVC (zFVC)
- Not suggestive of a norma small lung



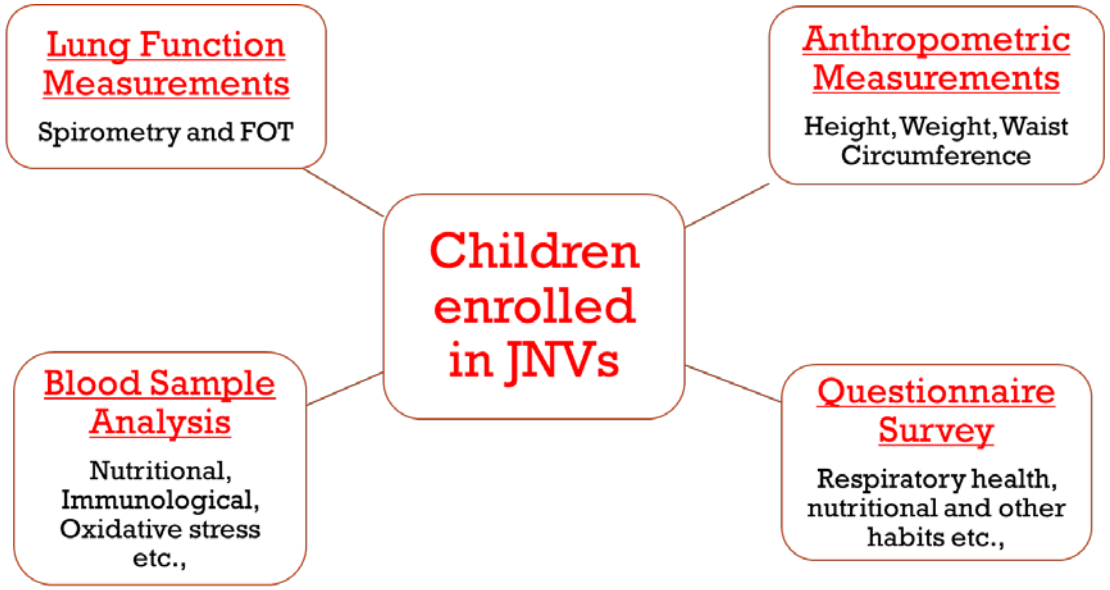
Study of lung function & its development (SOLID) in Indian children

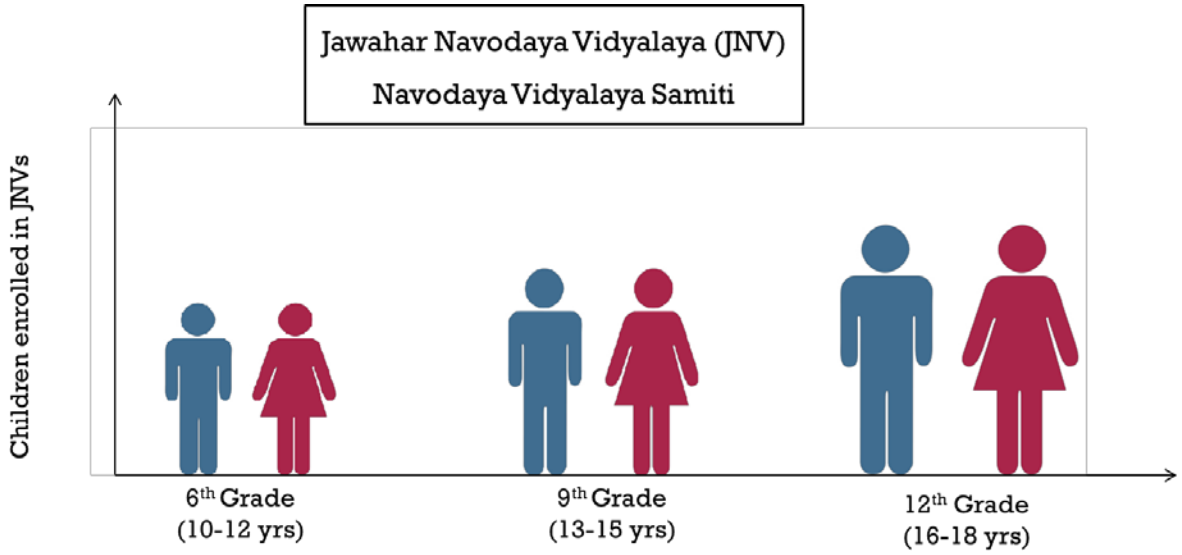
Nation of Nations

1. Geography:
   - Plains
   - Altitudes
   - Deserts

1. Sub-ethnicity:
   - Indo-Aryan
   - Mongoloid
   - Dravidian

1. Urban/Rural Profile:
   - Urban
   - Semi-Urban
   - Rural



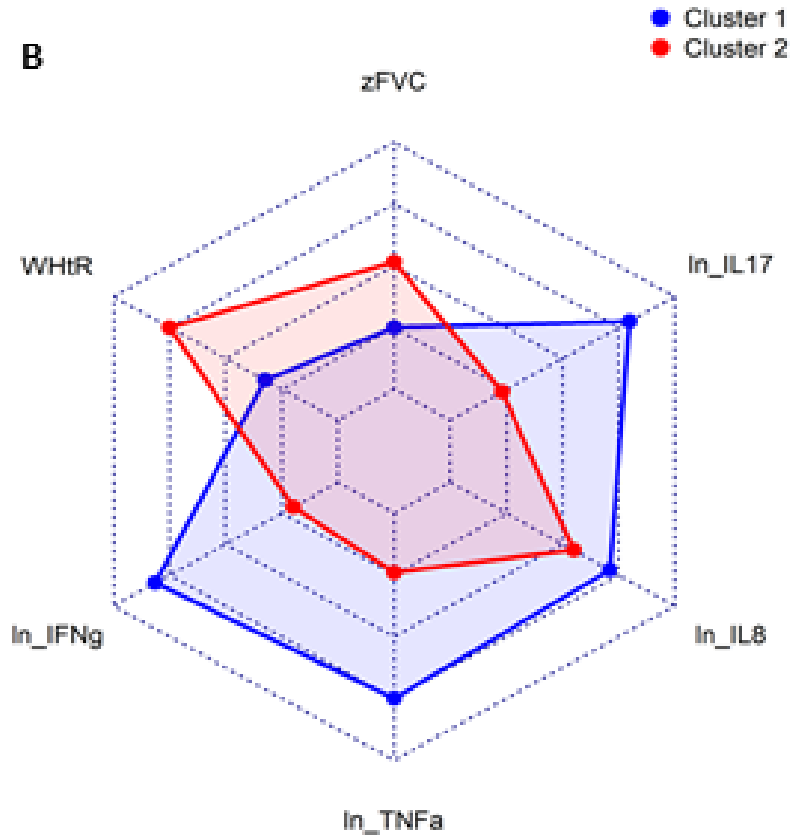


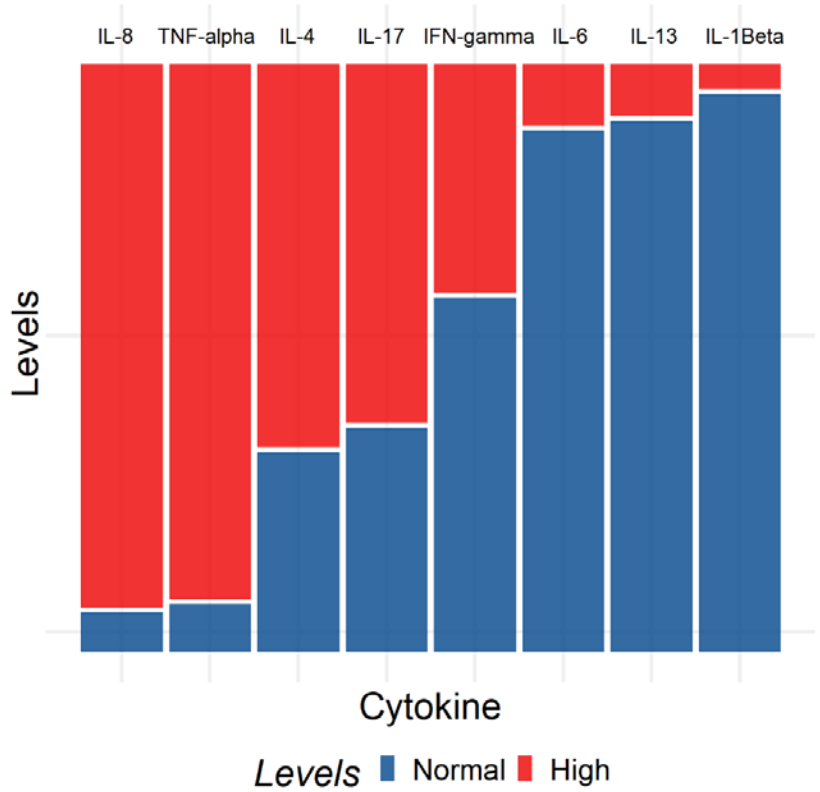
(Courtesy: Google Maps)

LOCATION	SUBJECTS
1. Chandigarh	186 (100 M, 86 F)
2. Jhajjar	189 (121 M, 68 F)
3. Bharatpur	162 (102 M, 60 F)
4. Jaisalmer	199 (144 M, 55 F)
5. Bengaluru	221 (131 M, 90 F)
6. Trivandrum	186 (95 M, 91 F)
7. Leh	172 (61 M, 111 F)
8. Puri	191 (121 M, 70 F)
9. Habra	172 (95 M, 77 F)
10. Mandi	196 (107 M, 89 F)
11 Ri-bhoi	170 (76 M, 94 F)
12. Phodong	164 (64 M, 100 F)
13. Pondicherry	200 (81 M, 119 F)
14. Gumla	203 (103 M, 100 F)
TOTAL	**2611 (1401 M, 1210 F)**

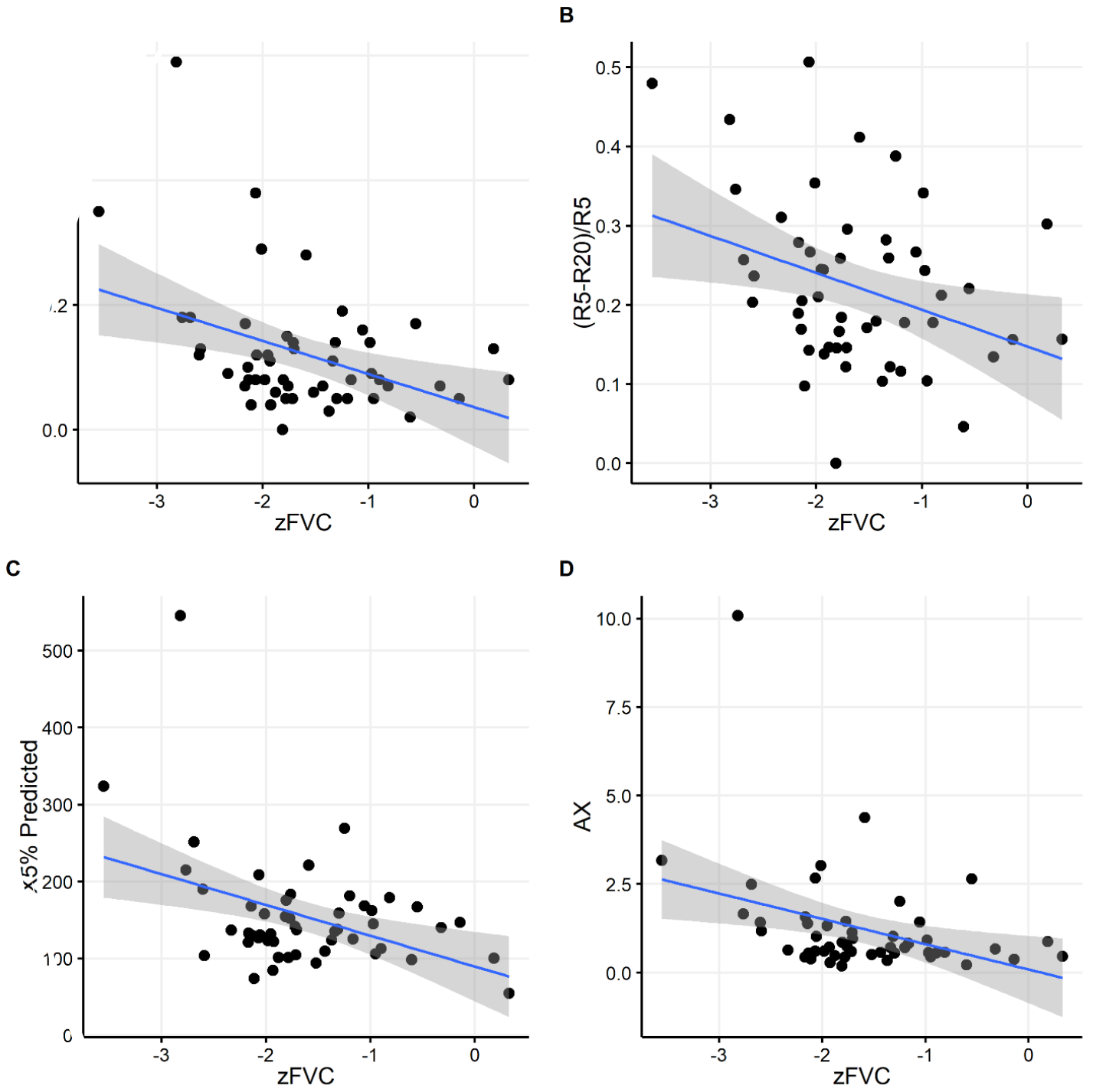
Adverse exposures may be driving low FVC in Indian children

- Inflammation, Thinness, and low vital capacity seen together in 40% of children



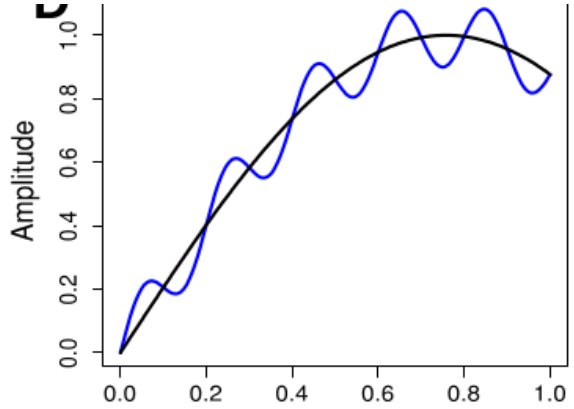


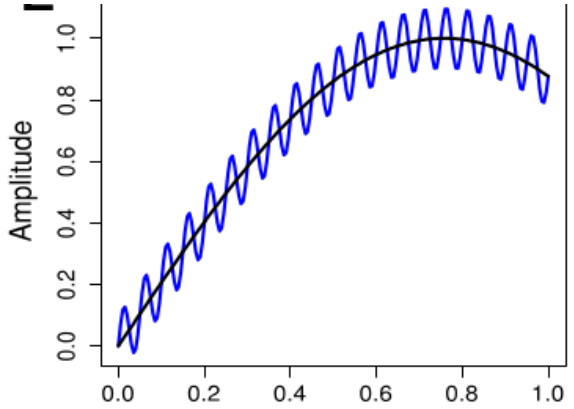
Small Airway Disease?



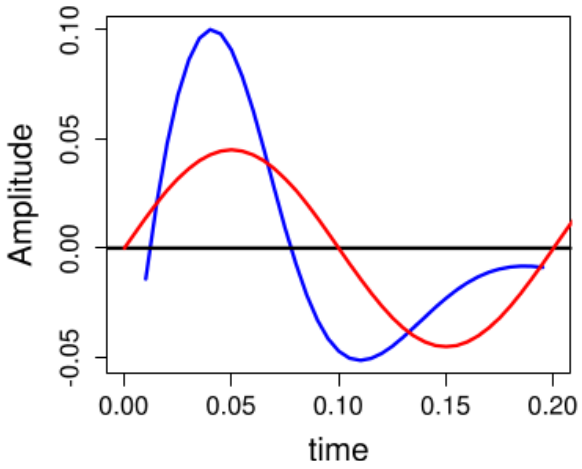
Oscillometry: Introduction

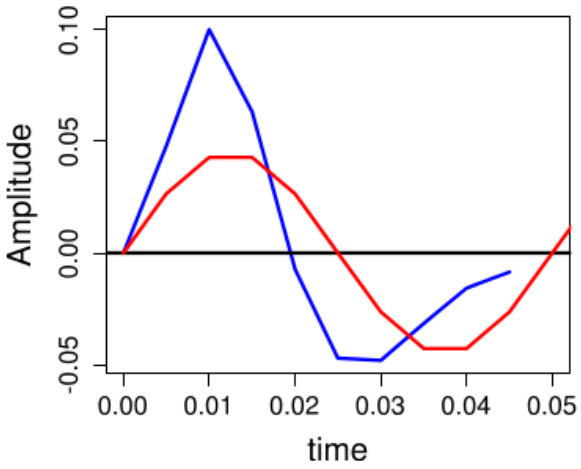
SINUSOIDAL PRESSURE APPLIED AT DIFFERENT FREQUENCIES WITHIN SINGLE BREATH





FLOW GENERATED: BLUE – RESISTANCE, RED – COMPLIANCE





$$Z_{rs}(f) = \frac{P_{rs}(f)}{V'_{rs}(f)}$$

$$Z_{rs}(f) = R_{rs}(f) + jX_{rs}(f)$$

LIMITATIONS OF EXISTING SOLUTIONS

- **Our Interviews revealed two problems with current devices (COSMED, VIASYS)**

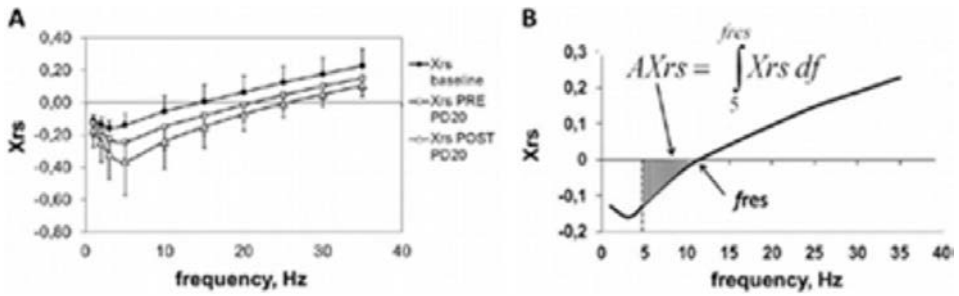
***Problem 1*: Devices are expensive and non-portable**

COSMED Quark i2m

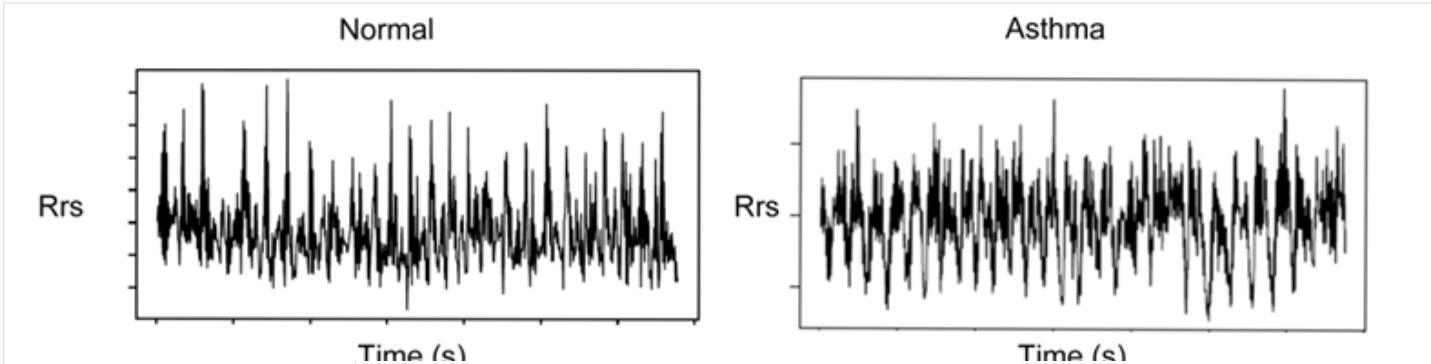
CareFusion IOS

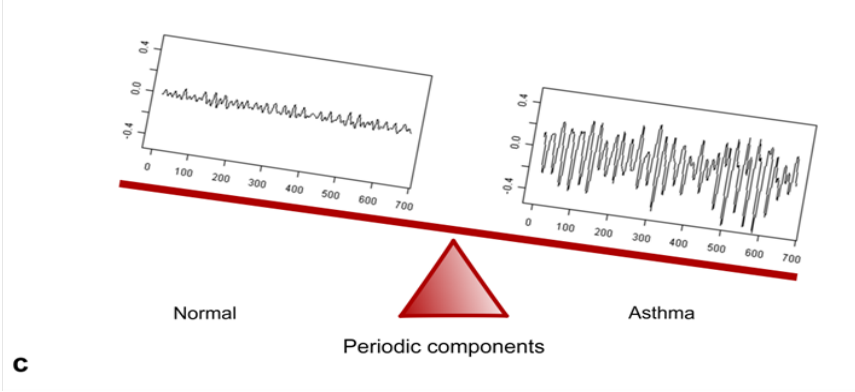
MedGraphics' ResMon

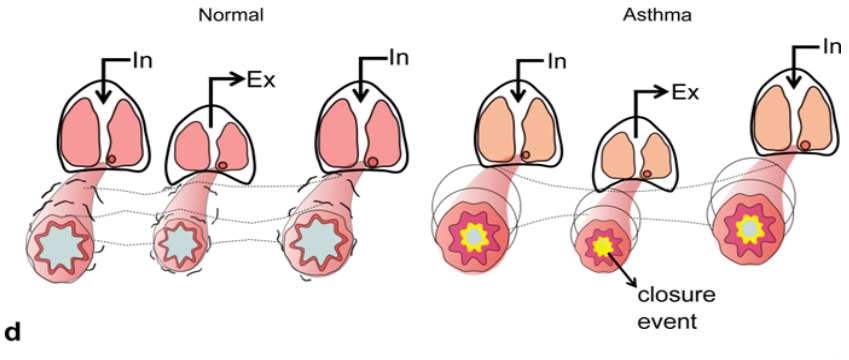
***Problem 2*: Data interpretation remains a challenge**



Pattern analysis of IOS data

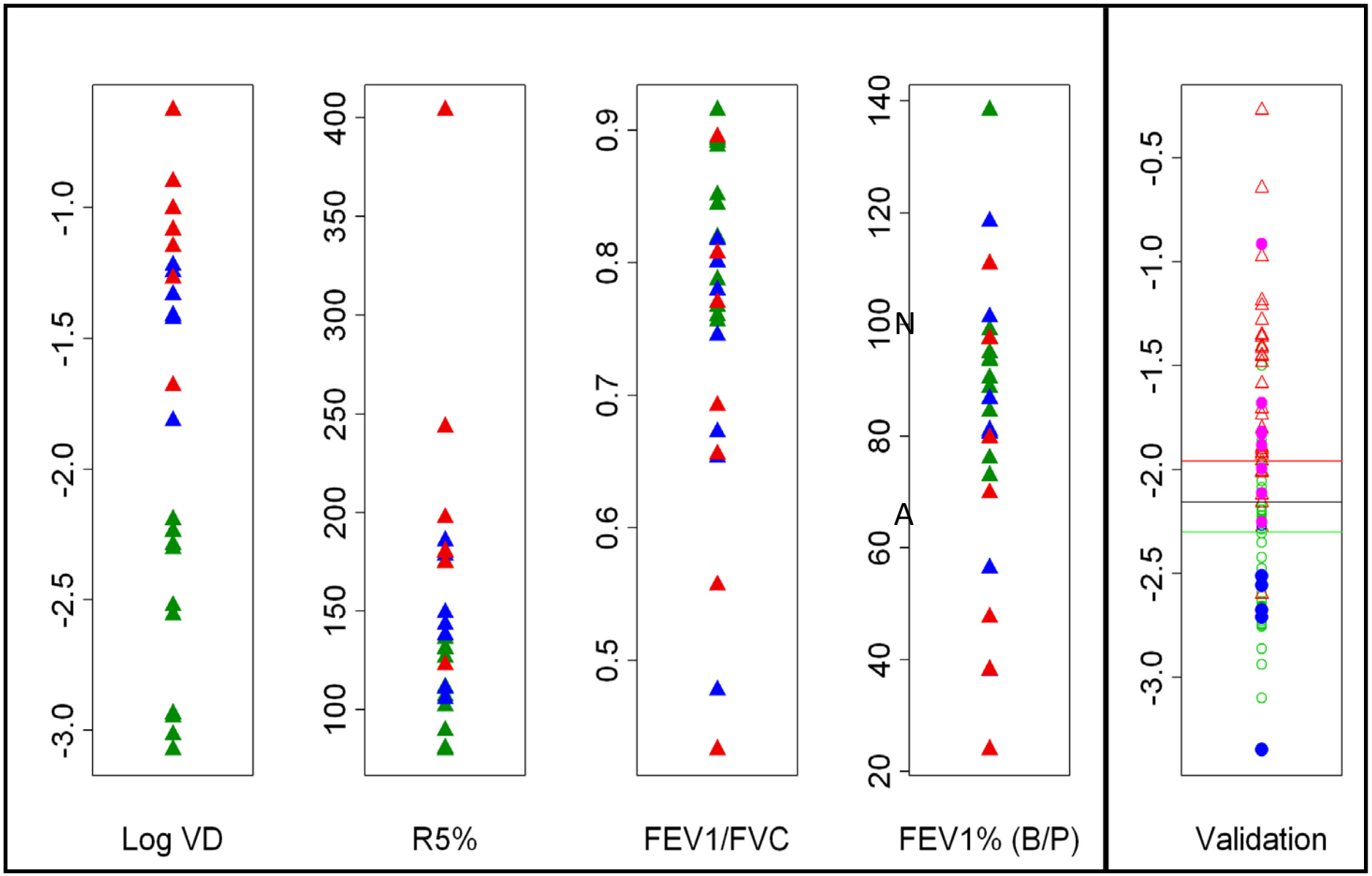




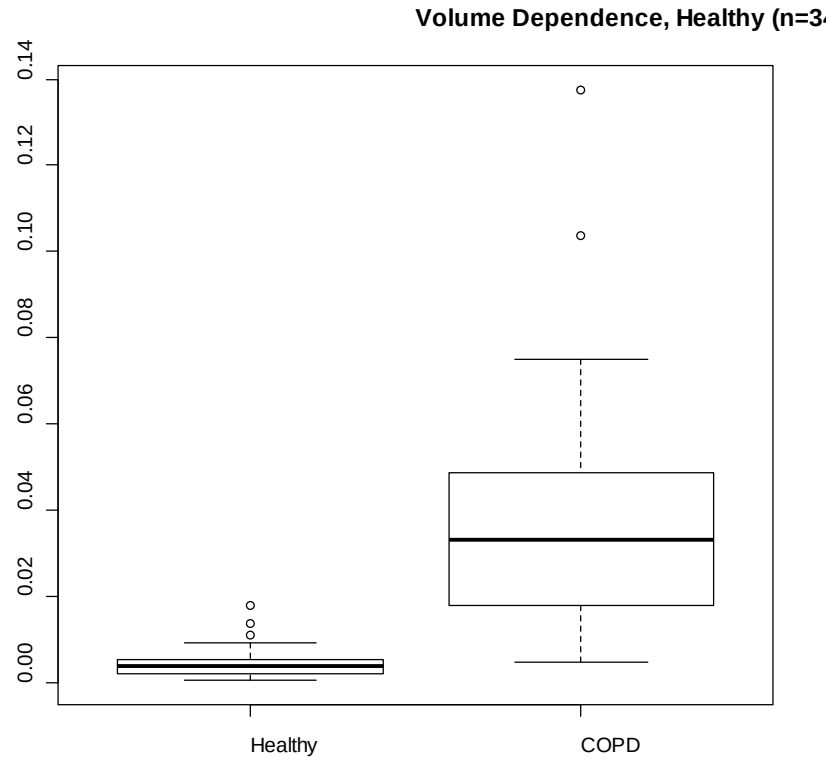


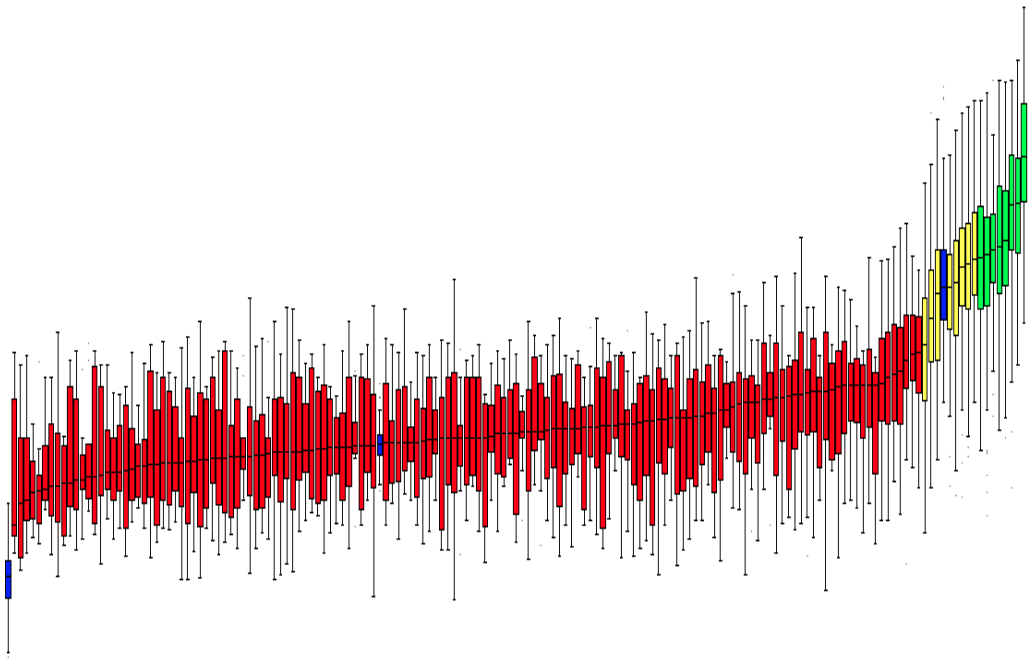
IGIB
Institute of Genomics & Integrative Biology

Superior Test Characteristics

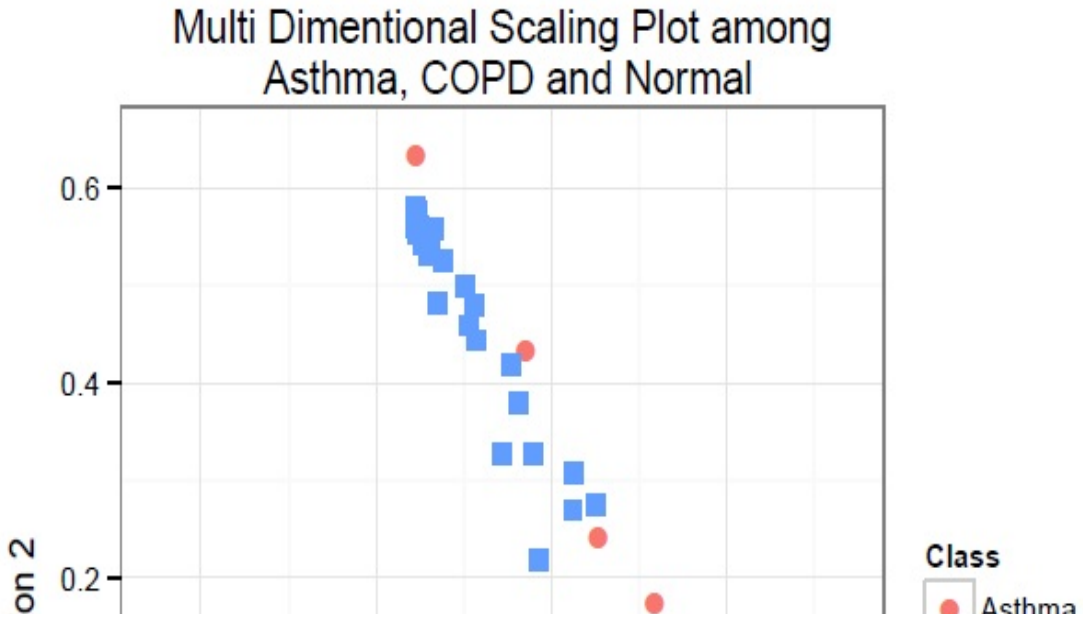


Picking most informative patterns: Artificial Learning (random forest)





Out of Box ERROR : 6.19 %



PREDICTED

ACTUAL

```
Confusion matrix:
   A  C  N class.
A 41  0  3   0.068
C  1 23  0   0.041
N  2  0 27   0.068
```

MIT Technology Review INNOVATORS UNDER 35 INDIA 2013

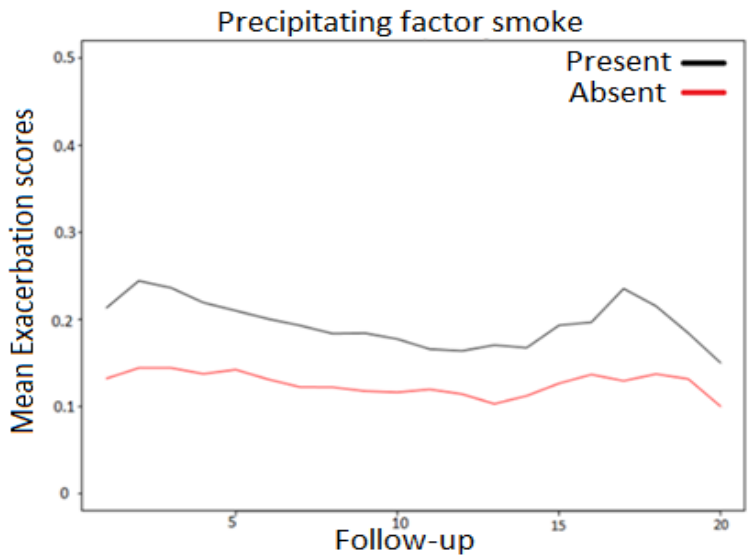
Tav Pritesh Sethi

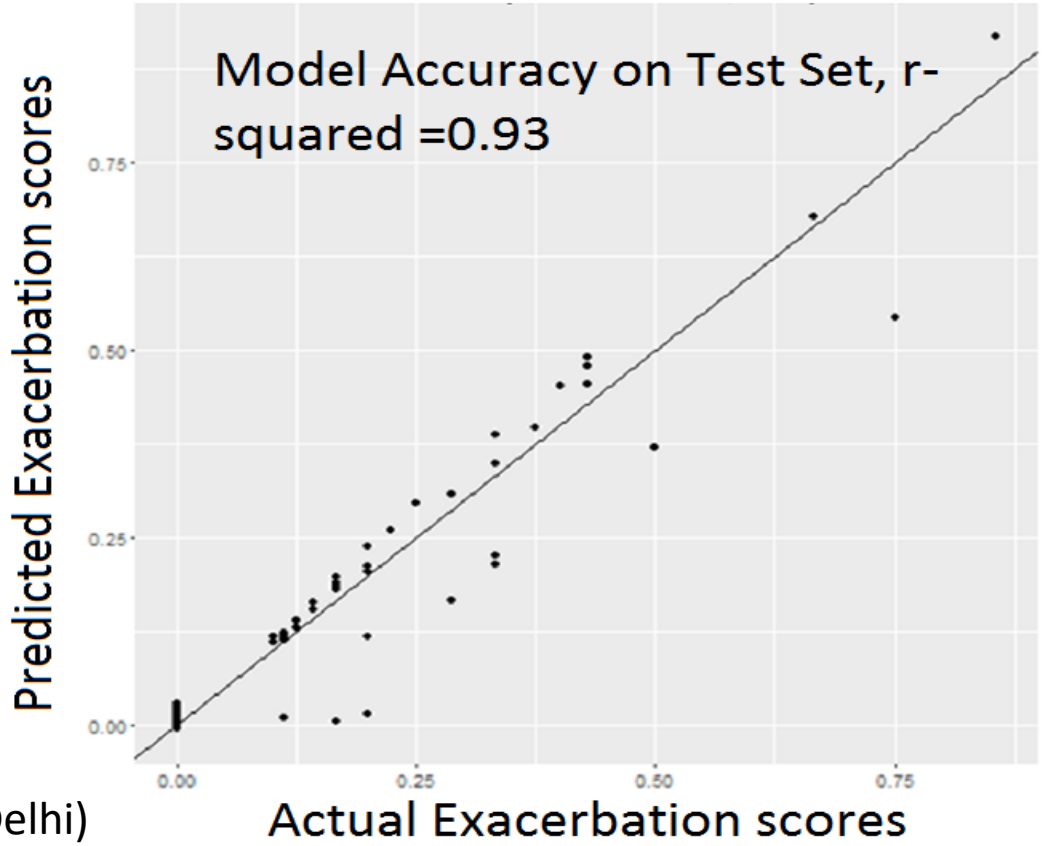
Tav Pritesh Sethi, 31

Tavpritesh Sethi developed an exquisitely sensitive test for small airway disease, using pattern recognition methods in the output data of impulse oscillometry. This is a very important advance, which should permit detection of airway disease in at-risk subjects such as cigarette smokers or biomass fuel exposed people, before the disease becomes advanced and usually irreversible.

Predicting asthma exacerbations

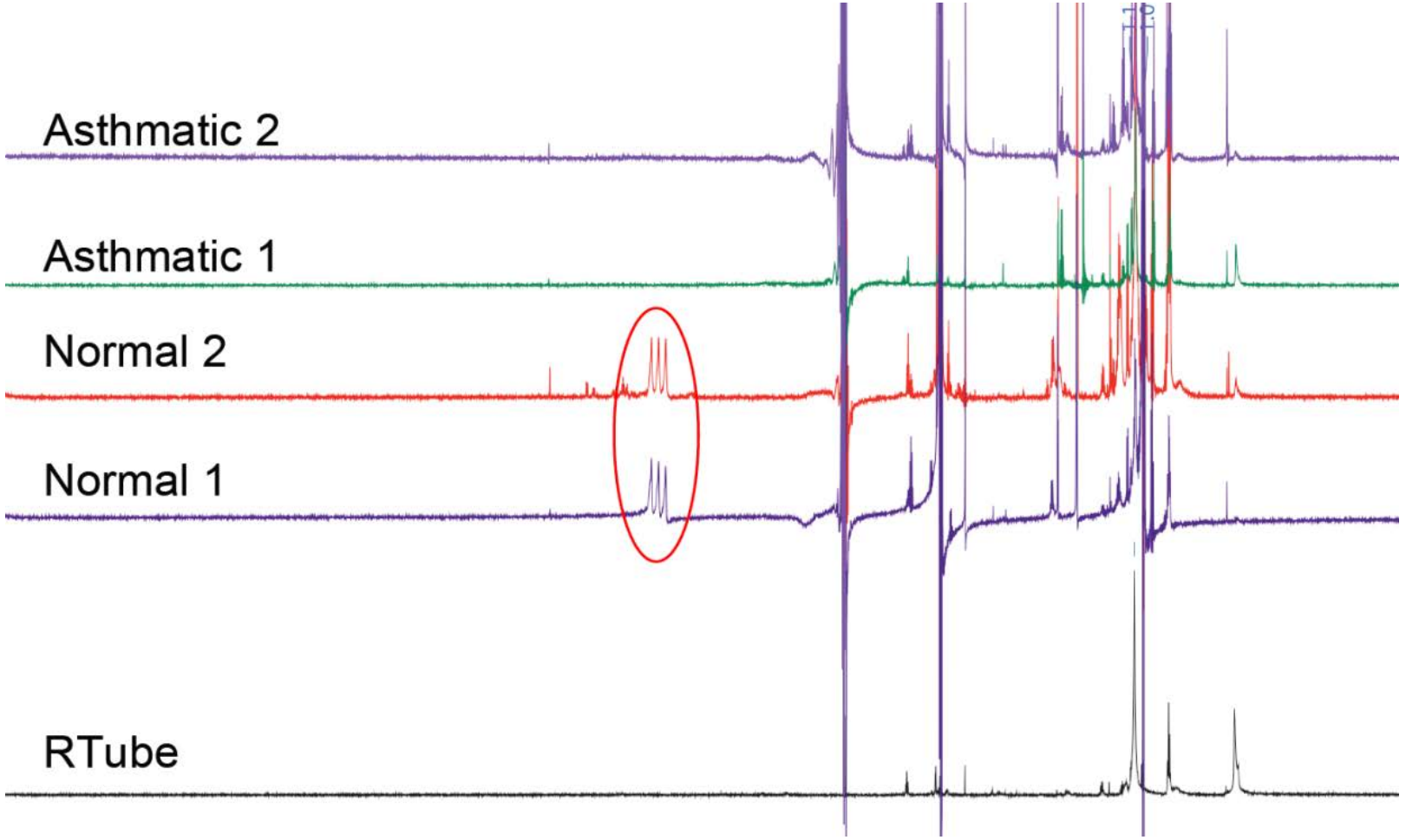
- Reactance variables are most predictive of future exacerbation, after history





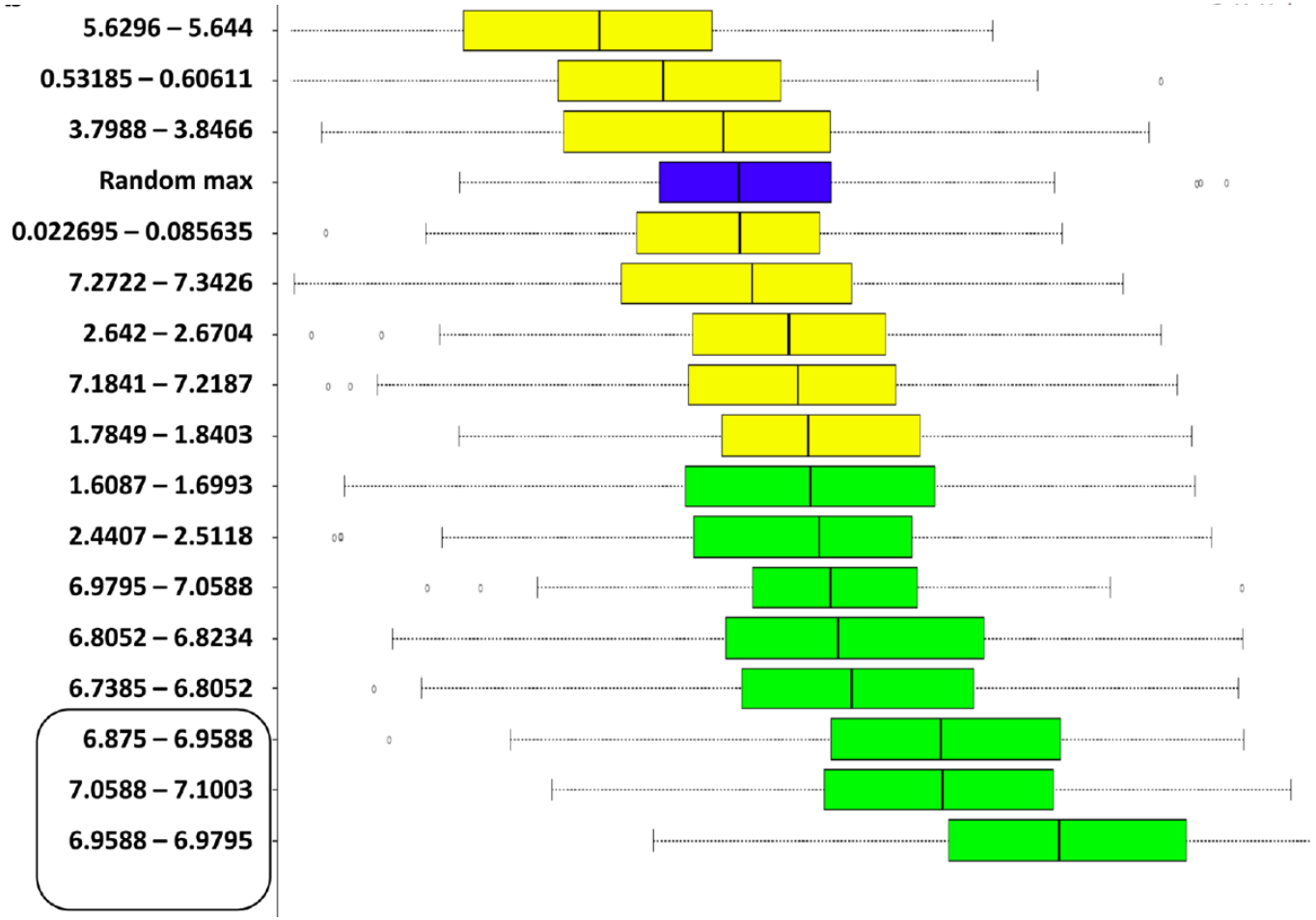
(Aditya Nagori, Rakesh Lodha, Tavpritesh Sethi AIIMS Delhi)

IV. Molecular endotypes: NMR spectroscopy of exhaled breath condensate



European Respiratory Journal, February 2012.

The ML approach



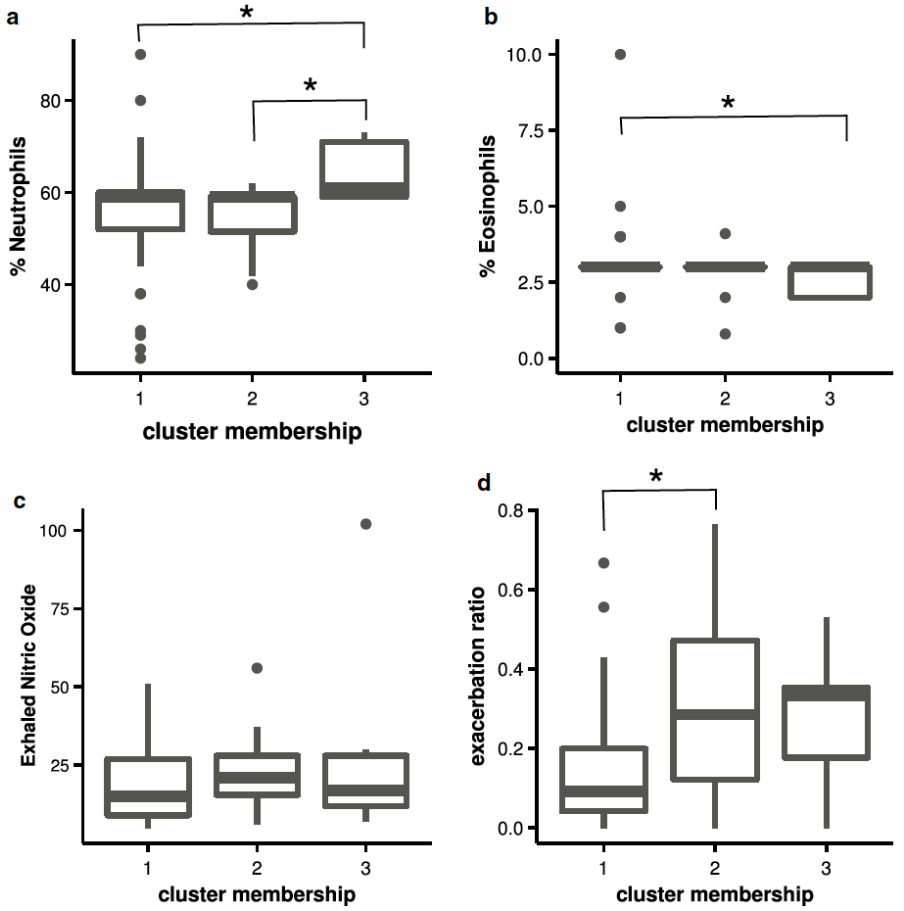
Sinha et al. J Transl Med (2017) 15:262
https://doi.org/10.1186/s12967-017-1365-7

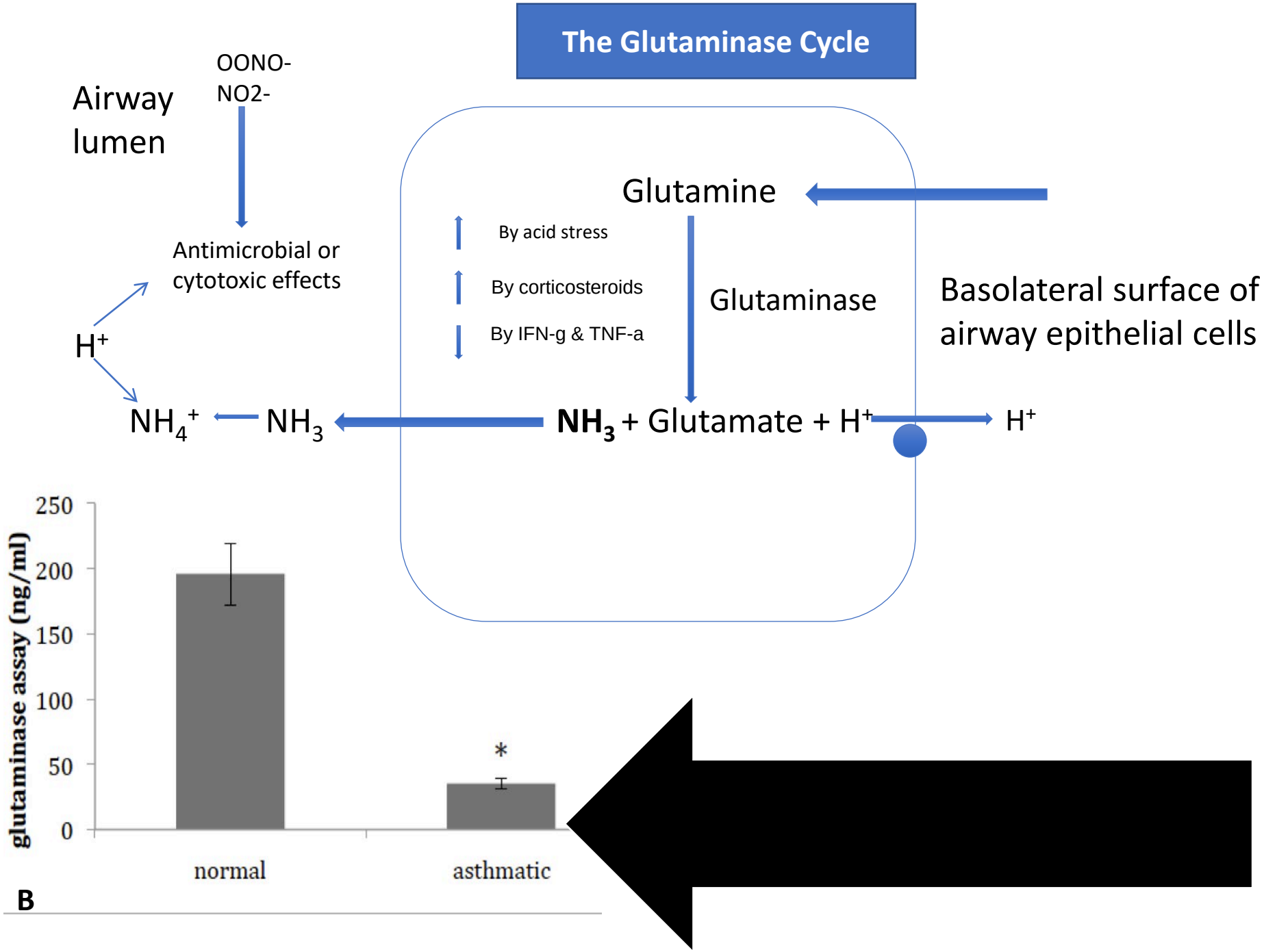
Journal of Translational Medicine

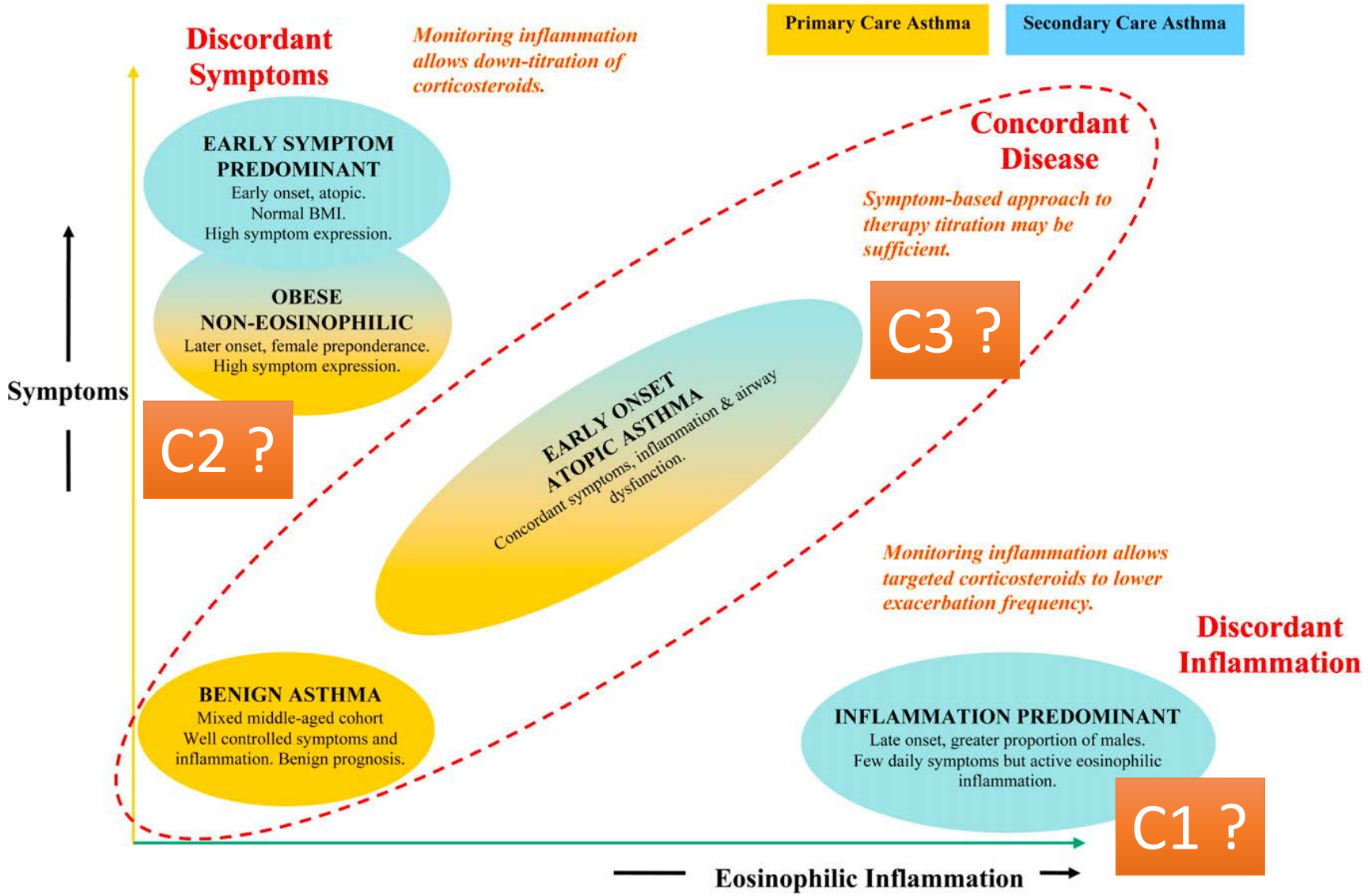
RESEARCH Open Access

Exhaled breath condensate metabolome clusters for endotype discovery in asthma

Anirban Sinha[5†], Koundinya Desiraju[1,2†], Kunal Aggarwal[1], Rintu Kutum[1,2], Siddhartha Roy[7], Rakesh Lodha[3], Balaram Ghosh[1], Tavpritesh Sethi[3,6*] and Anurag Agrawal[1,2,4*]




The Glutaminase Cycle
Airway lumen
OONO-
NO2-
Antimicrobial or cytotoxic effects
Glutamine
By acid stress
By corticosteroids
By IFN-g & TNF-a
Glutaminase
Basolateral surface of airway epithelial cells
H+
NH4+
NH3
NH3 + Glutamate + H+
H+
glutaminase assay (ng/ml)
250
200
150
100
50
0
normal
asthmatic
*
B

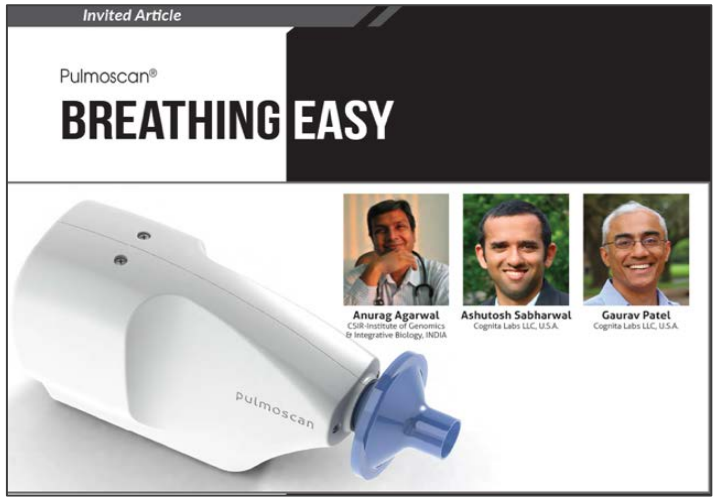


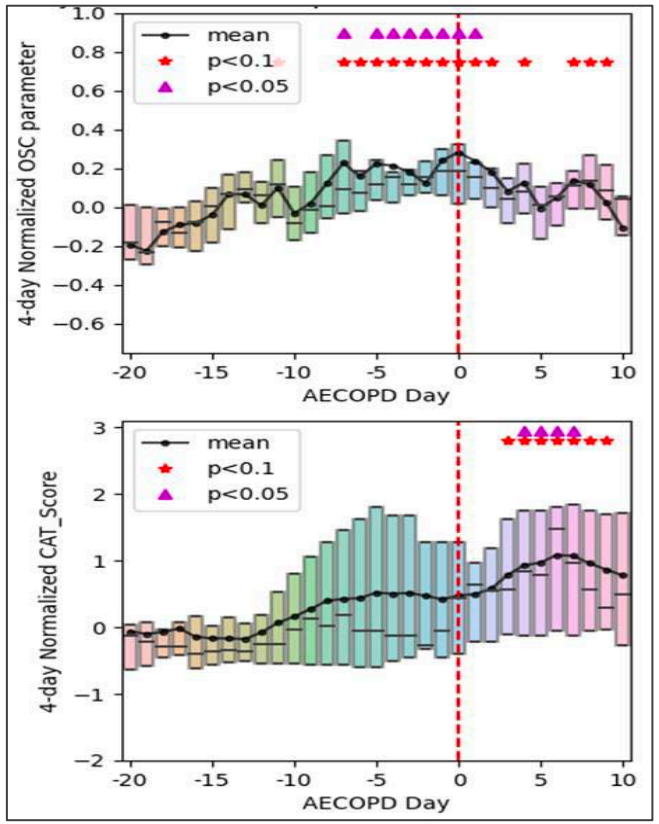
Haldar et al AJRCCM 2008

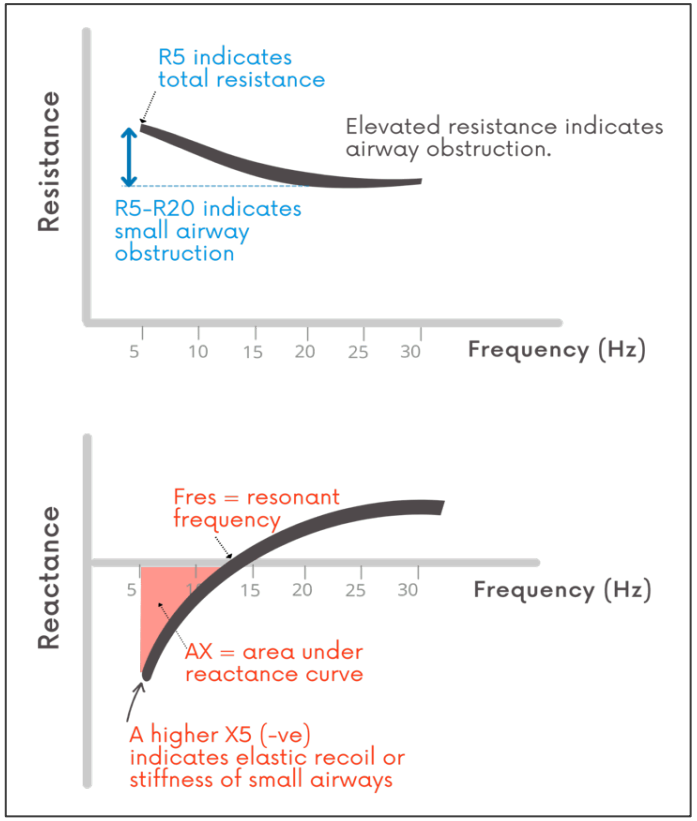
Cluster Analysis and Clinical Asthma Phenotypes

Predicting COPD Exacerbations

- Pulmoscan – portableoscillometer for office / home use scenario
- No impulses, only continuous multifrequency pressure sine waves
- FDA approved
- Pilot Studies ongoing for exacerbation algorithm development







Cognita Labs, ATS 2023)

Are you feeling sleepy?

- Yet?

npj | Digital Medicine

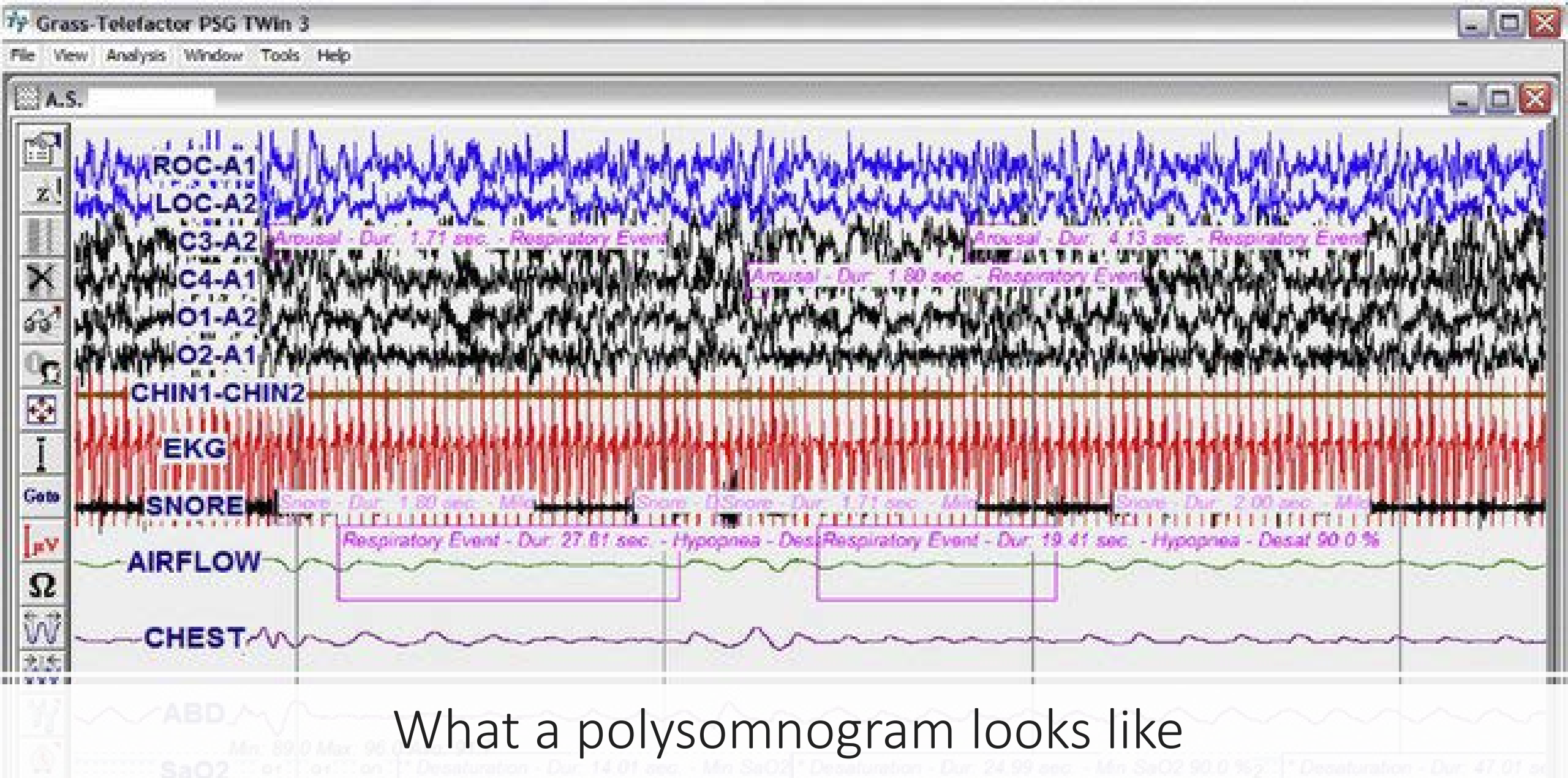
www.nature.com/npjdigitalmed

REVIEW ARTICLE OPEN

Check for updates

The future of sleep health: a data-driven revolution in sleep science and medicine

Ignacio Perez-Pozuelo[1,2]✉, Bing Zhai[3], Joao Palotti[4,5], Raghvendra Mall[4]✉, Michaël Aupetit[4], Juan M. Garcia-Gomez[6], Shahrad Taheri[7], Yu Guan[3] and Luis Fernandez-Luque[4]

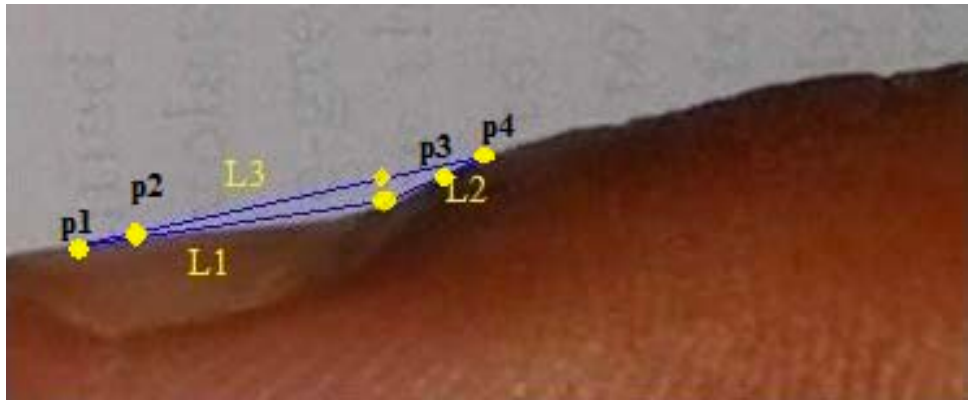


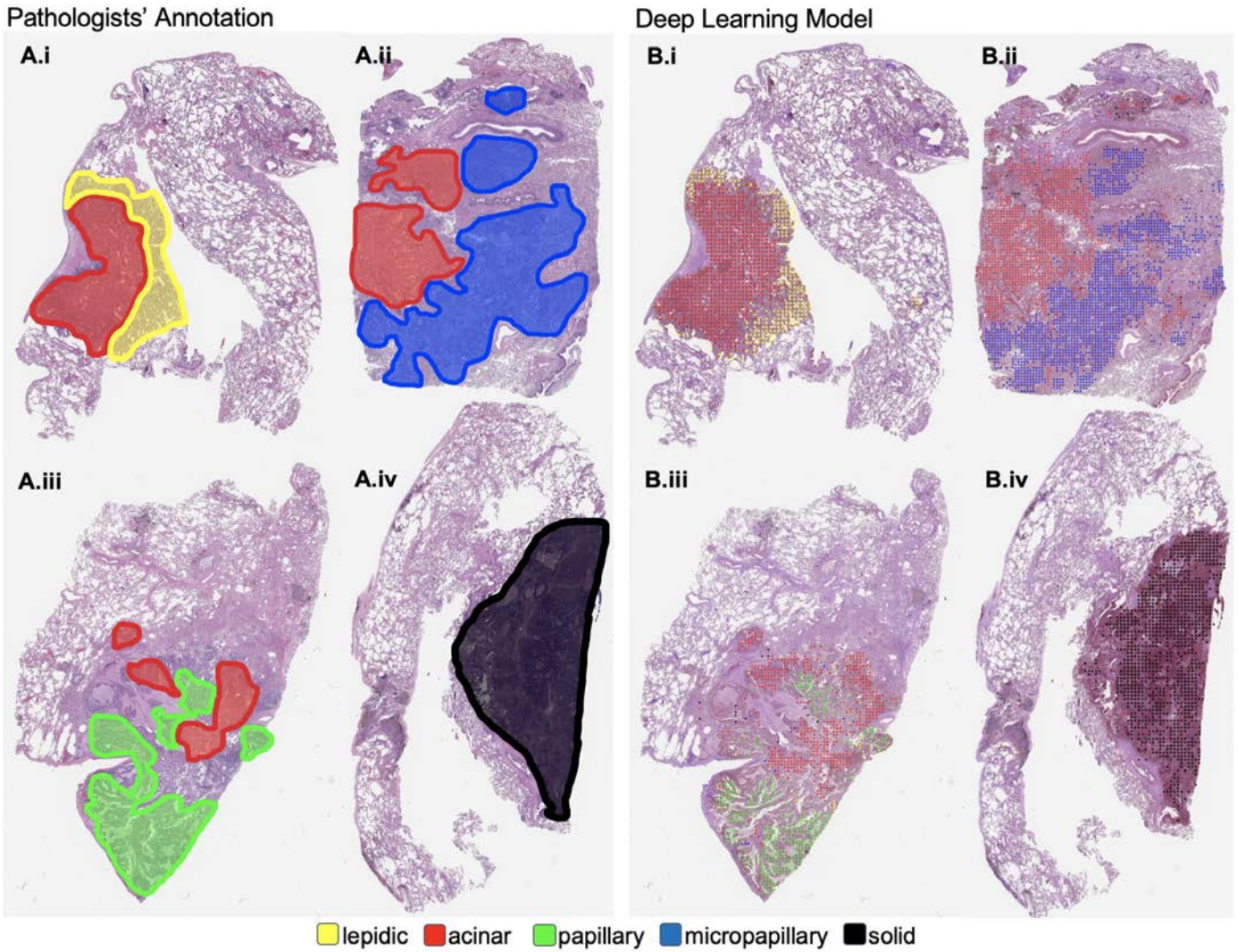
What a polysomnogram looks like

New directions

V. Images are most suited to AI

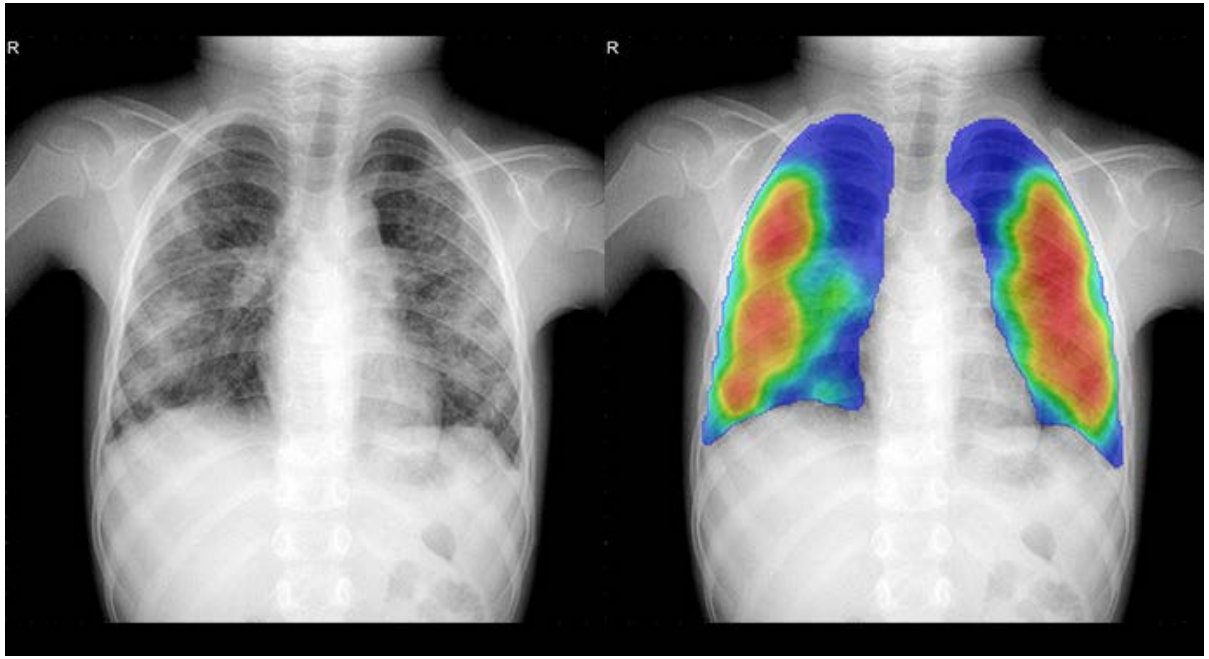
- From fingers to cells





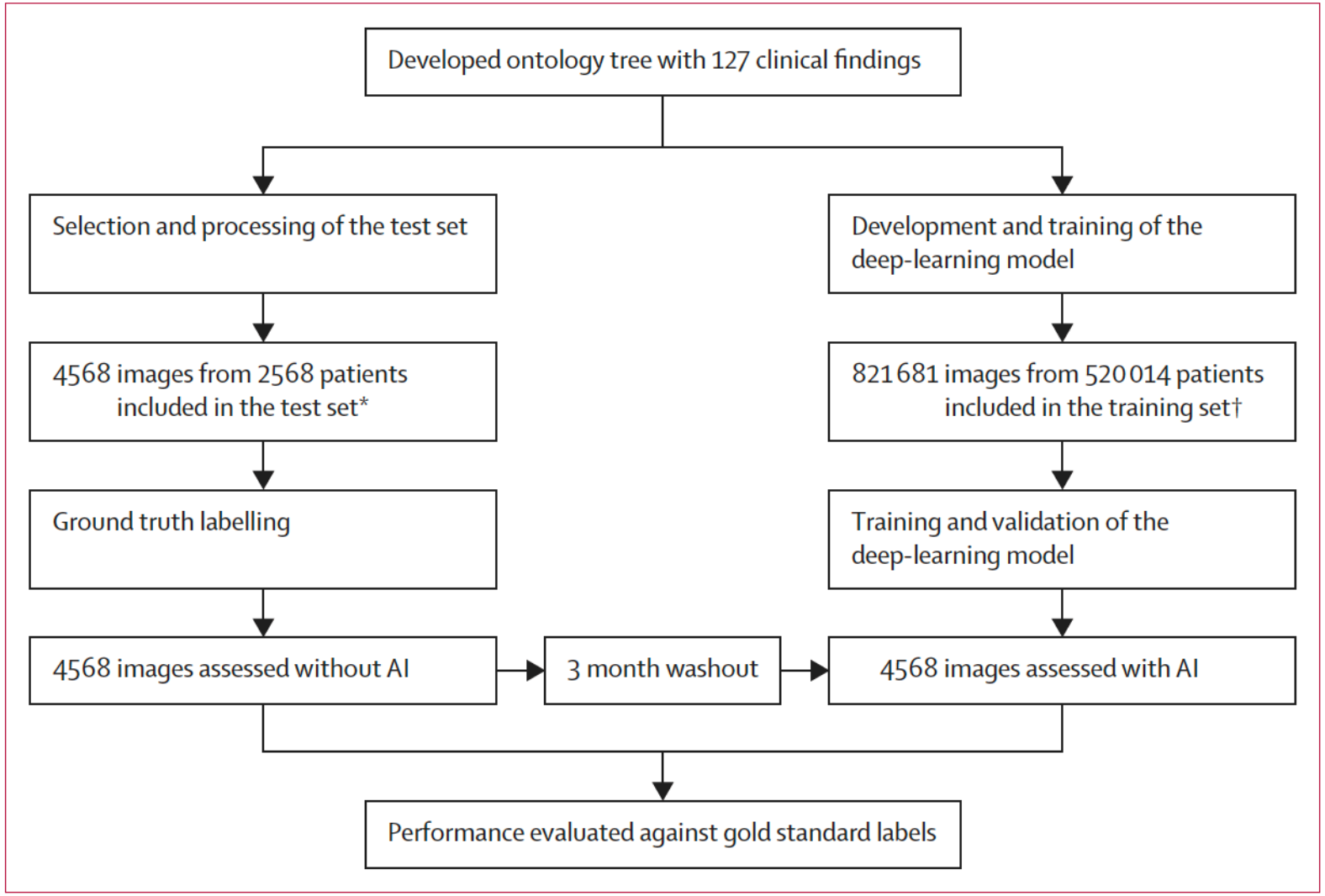
Chest X Ray: The ubiquitous test for lung disease

- AI interest in CxR interpretation accelerated sharply with CAD4TB
- Currently at v6, many new players (QureAI, India). Working well for case referred for Tuberculosis. Comparable to human radiologist



AI for CxR getting better and better for findings

- Seah et al Lancet 2021
- Model classification alone was significantly more accurate than unassisted radiologists for 117 (94%) of 124 clinical findings predicted by the model and was non-inferior to unassisted radiologists for all other clinical findings.



What is ‘autonomous reporting’ in medical imaging?

Autonomous AI reporting in medical imaging means that an AI application produces the final report of the imaging study – without any involvement from a human doctor. The AI produces a final diagnosis on its own, on which the future treatment decisions will be made.

SCIENCE / HEALTH

Autonomous X-ray-analyzing AI is cleared in the EU

Oxipit Awarded CE Mark for the First Autonomous AI Medical Imaging Application

on chest X-rays featuring no abnormalities

Findings are different from diagnosis, but an essential and desirable step

- Diagnosis is a Bayesian art and needs clinical context
- AI is now better than most clinicians for identifying findings in studies
- Treatment is even more context dependent
- Problems in AI based diagnosis, without independent findings step
  - Opacity
  - Hidden stratification
  - Low generalizability to new datasets

Validation of expert system enhanced deep learning algorithm for automated screening for COVID-Pneumonia on chest X-rays

Prashant Sadashiv Gidde, Shyam Sunder Prasad, Ajay Pratap Singh, Nitin Bhatheja, Satyartha Prakash, Prateek Singh, Aakash Saboo, Rohit Takhar, Salil Gupta, Sumeet Saurav, Raghunandanan M. V., Amritpal Singh, Viren Sardana, Harsh Mahajan, Arjun Kalyanpur, Atanendu Shekhar Mandal, Vidur Mahajan, Anurag Agrawal, Anjali Agrawal ✉, Vasantha Kumar Venugopal ✉, Sanjay Singh ✉ & Debasis Dash ✉

How can we put it together?

- Foundational AI, with verifiable grounding of key steps
  - Combining LLM with computer vision finding detection seems useful

XrayGPT: Chest Radiographs Summarization using Large Medical Vision-Language Models

Omkar Thawkar[1] Abdelrahman Shaker[1] Sahal Shaji Mullappilly[1] Hisham Cholakk
Rao Muhammad Anwer[1,2] Salman Khan[1] Jorma Laaksonen[2] Fahad Shahbaz Khan

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Papers arxiv:2306.00890

LLaVA-Med: Training a Large Language-and-Vision Assistant for Biomedicine in One Day

Published on Jun 1 · Featured in Daily Papers on Jun 2

Authors: Chunyuan Li, Cliff Wong, Sheng Zhang, Naoto Usuyama, Haotian Liu, Jianwei Yang, Tristan Naumann, Hoifung Poon, Jianfeng Gao

Thank you

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