Future Care

Sensors, AI & the Reinvention of Medicine

Jag Singh MD ScM DPhil

Mass General Brigham

Conflict of Interest Disclosure

Consulting:

Abbott Inc, Biotronik Inc, Biosense Webster, Boston Scientific, Cardiologs Inc, Carelog Inc, CVRx Inc, EBR Inc, Impulse Dynamics, Implicity Inc, I-Rhythm Inc, Medtronic Inc, Medscape Inc, Microport Inc, Notal Vision, Orchestra BioMed Inc, Phillips (Bio-Tel), Sanofi Inc, Smart Cardia Inc & Vektor Medical Inc.

Research:

Heart Rhythm Society

American College of Cardiology

Abbott Inc, Biotronik Inc, Boston Scientific, Cardiologs Inc, EBR Inc, Medtronic Inc, Sanofi, SentiAR Inc.

Stock Options / Equity :

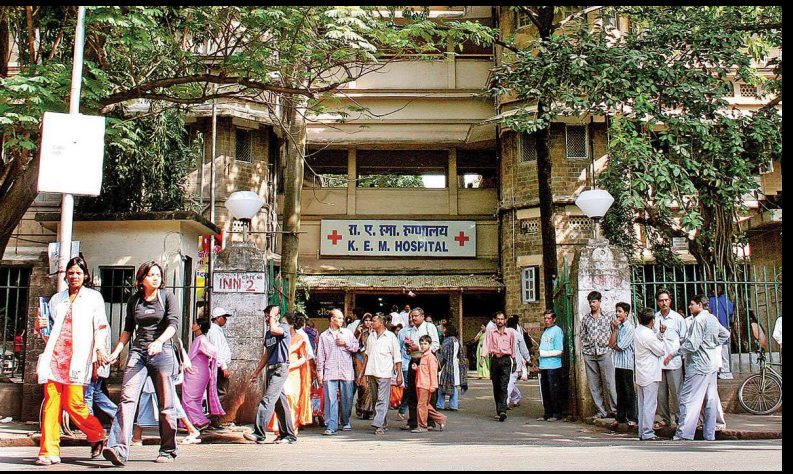
Smart Cardia, Orchestra Biomed, Carelog Inc.

My objectives

- Gaps in our Healthcare System
- Role of Sensors in Care Delivery
- The Data Conundrum & Role of AI in Healthcare
- Future Models of Clinical Care

Change is not merely necessary to life – it is life

Alvin Toffler

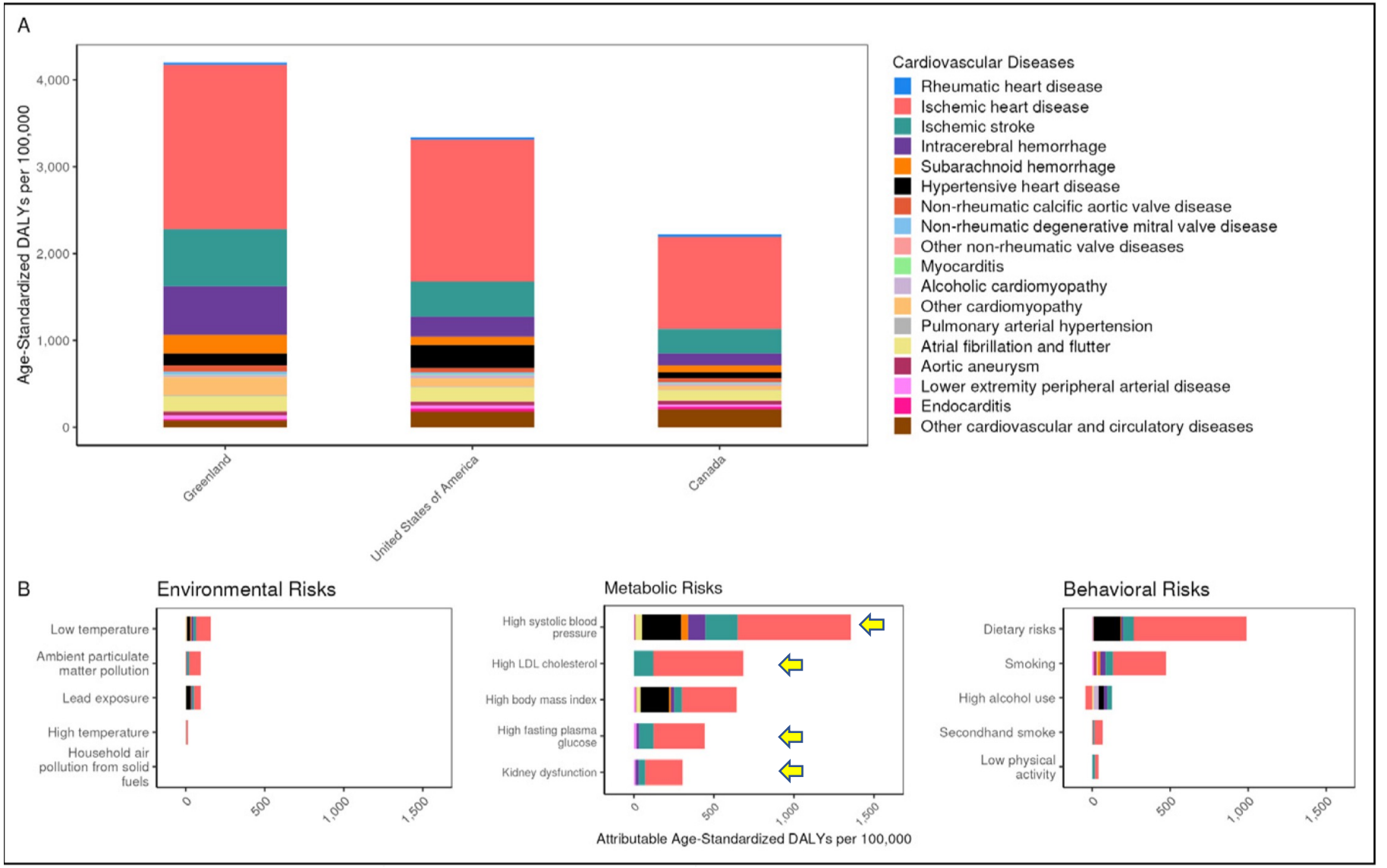


- Journey across 3 healthcare systems

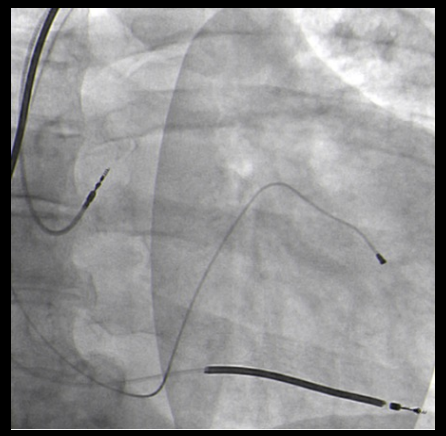
US Healthcare System

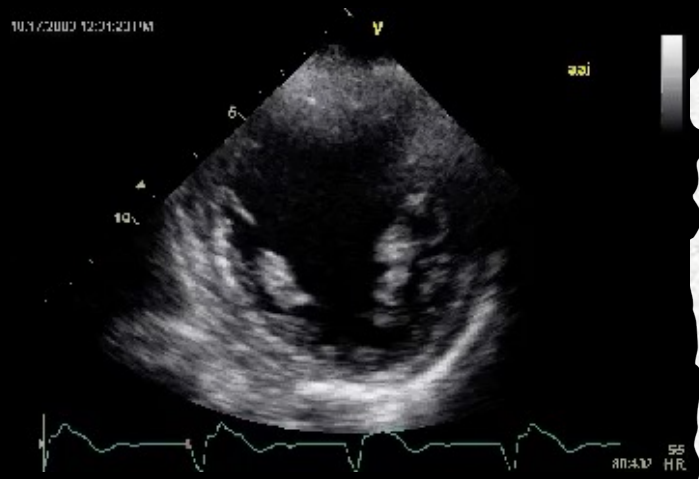
- Big, Fat & Sick!
- nearly 1/5th of GDP
- Some concerns
  - I's & O's
  - Culture of margins
  - Living Contradiction
    - 3 of 4 $- chronic diseases
    - Our wellness depends on sickness

Cardiovascular Disease Burden & Contributors



JACC VOL. 82, NO. 25, 2023
DECEMBER 19/26, 2023:2351-2352

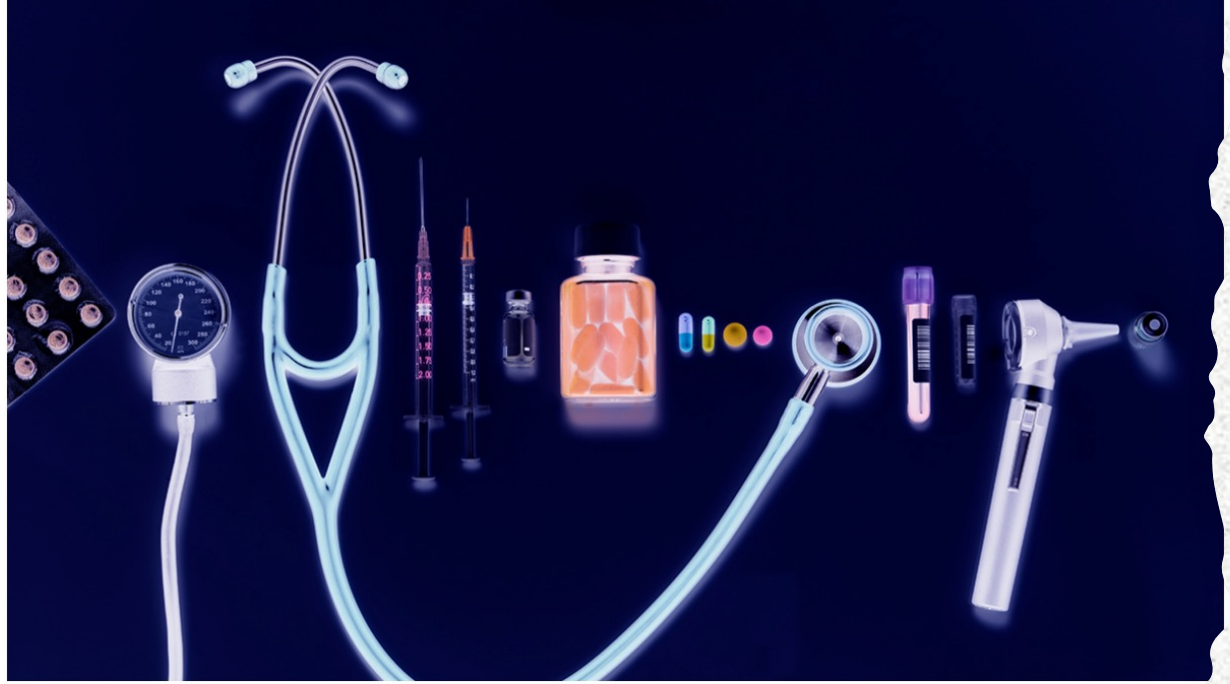




Paul's Story

- 2003
- 71-year-old
- 3 Chronic diseases
- End organ damage
- Hemodialysis for 7 years

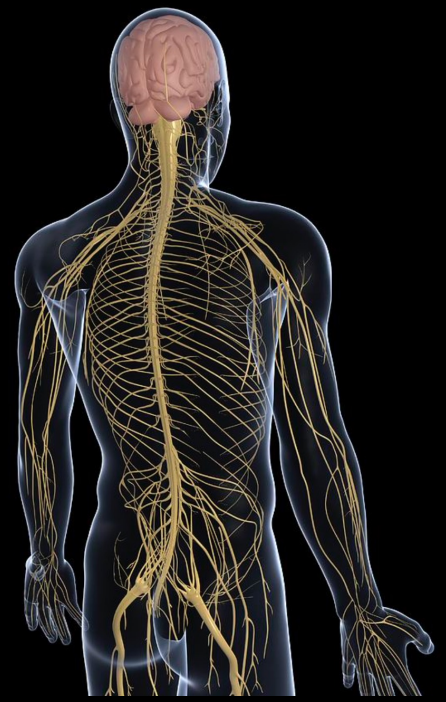
- What went wrong?



- Main story in medicine is finding a tenable life with disease
- Bridging gaps between patient expectations and workings of a busy hospital
- We are now blessed with -
  - Data
  - Unlimited connectivity
  - Massive processing power

Future of Care will be -

- Virtual
- Sensor-aided
- Powered by AI
- Remote monitoring
- Sustainable Workflows

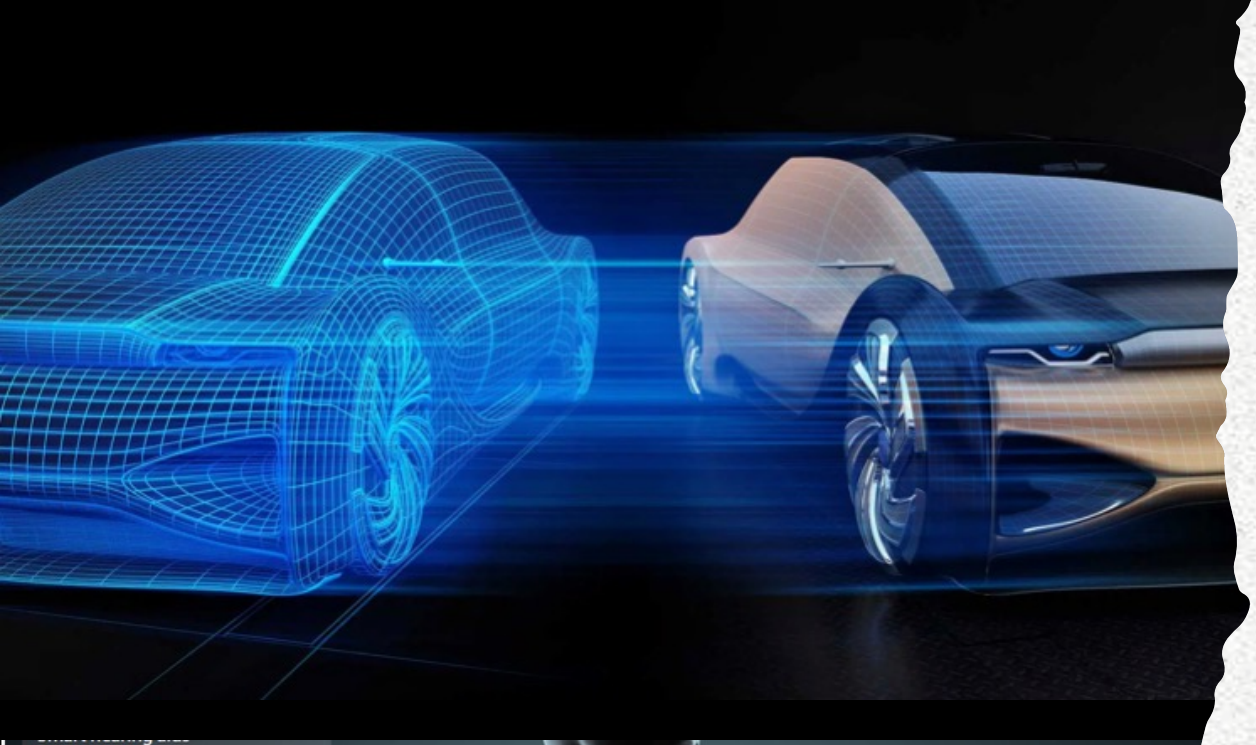


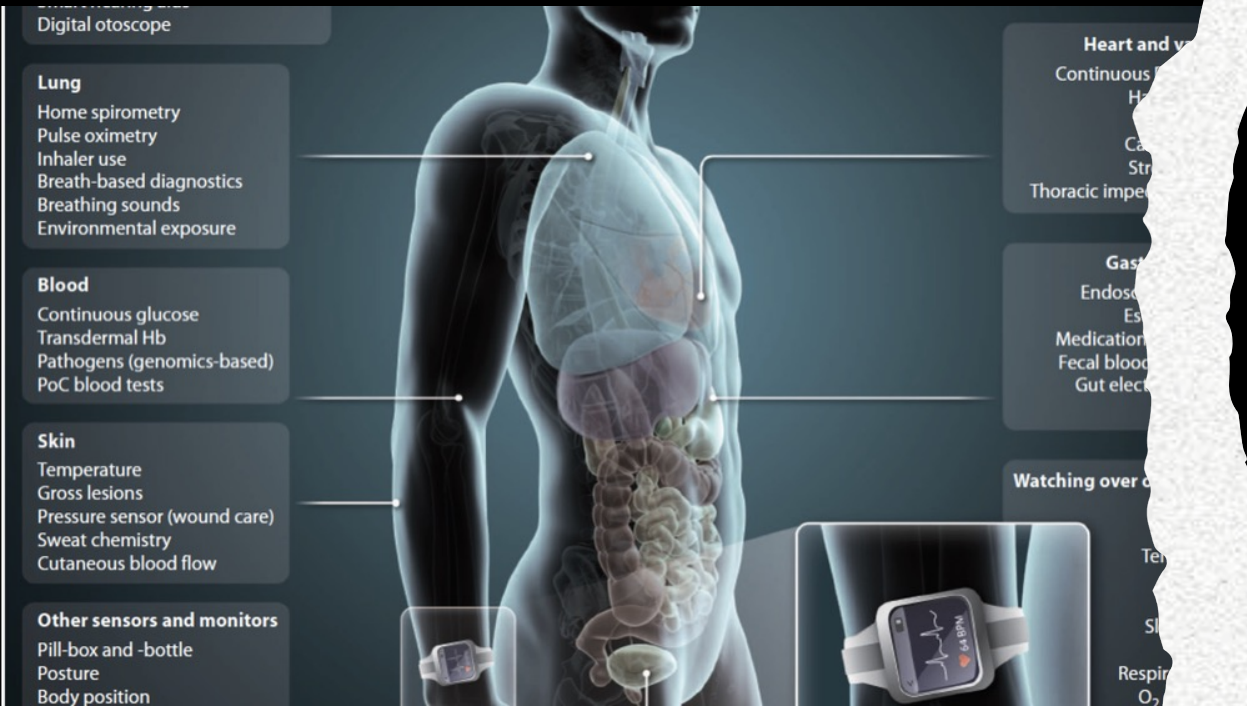
- All knowledge begins with the senses

  - *Emmanuel Kant*

- Analog experience = electric charge

- Every cell /every organ – operates through a sequence of binary codes





- Digitizing the human body & digital dashboards
- Automobile equivalent Check Engine Light
- Provides the opportunity to monitor, forecast, and proactively intervene

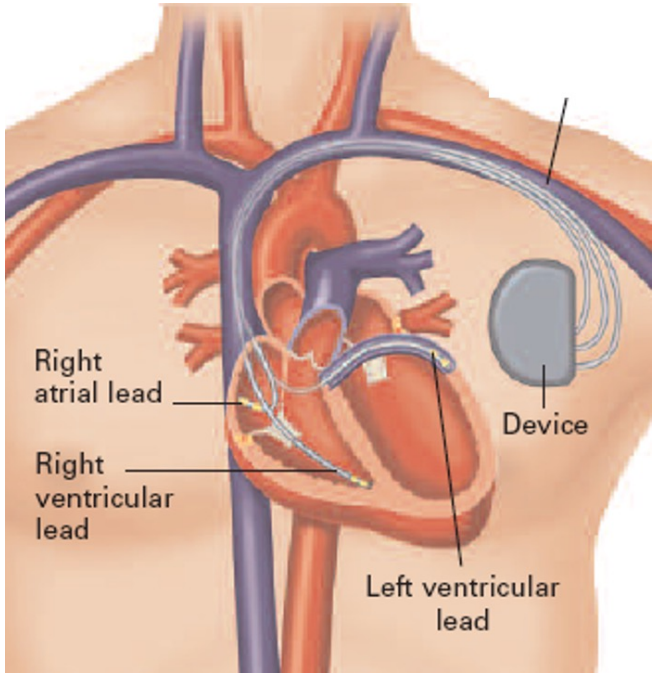
Device-based Sensors

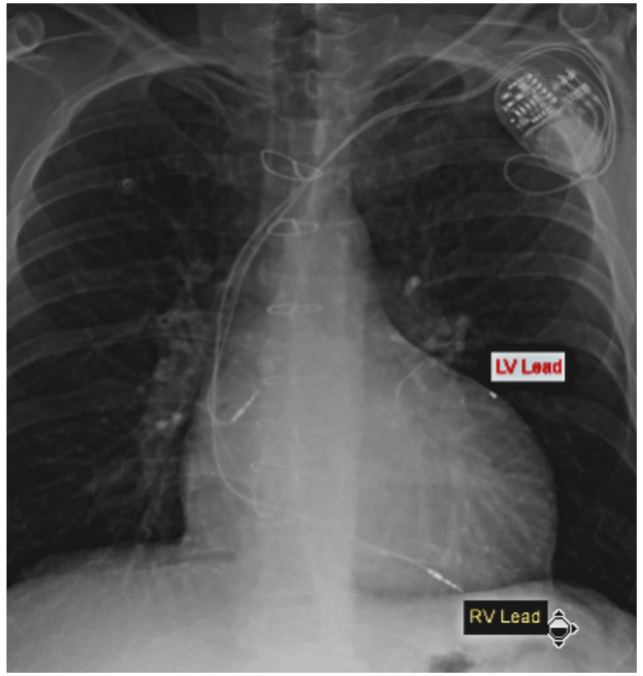
- this is not new!

- Simple Sensors
  - Heart rate and derivatives
  - Accelerometers
  - Impedance derived measures
  - Heart sounds
  - Respiratory

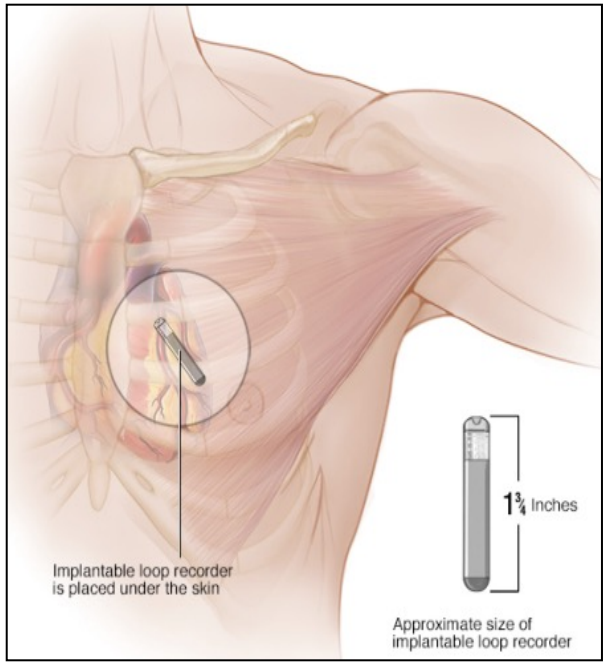
- Sophisticated Sensors
  - Pressure: left atrial pressure, pulmonary artery pressure, RV dP/dt, etc.
  - Heart Sound: PEA
  - C Output: Doppler
  - Chemicals: PO_2, PCO_2, pH, electrolytes and glucose
  - Biomarkers: TNF, BNP, etc.

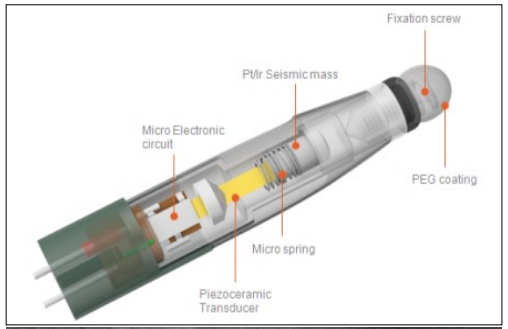
Merchant F, Dec GW and Singh JP. Circulation EP, 2010:3: 357

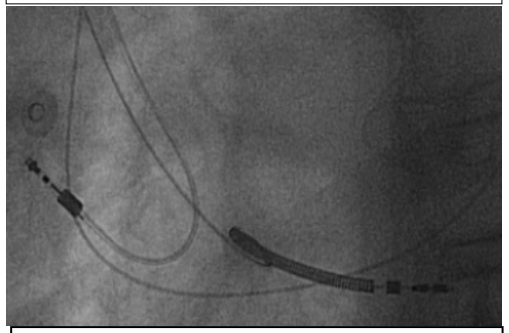


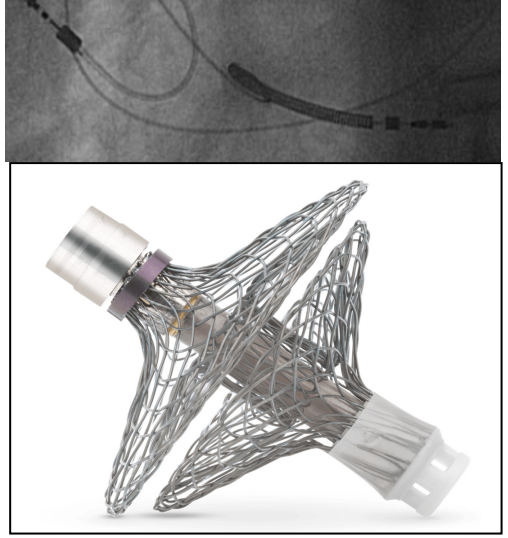


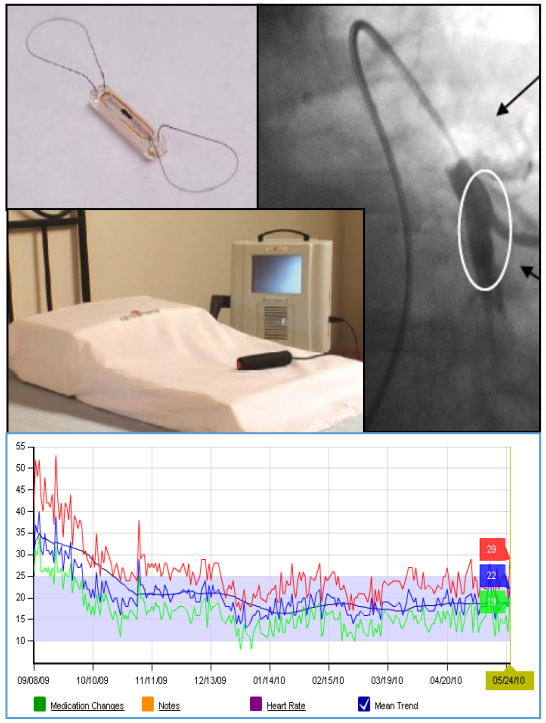
Stand-alone Implantable Sensors

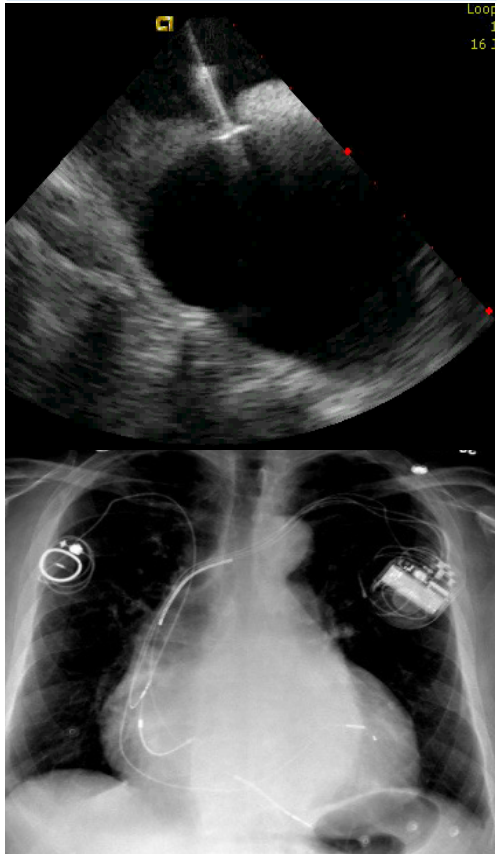










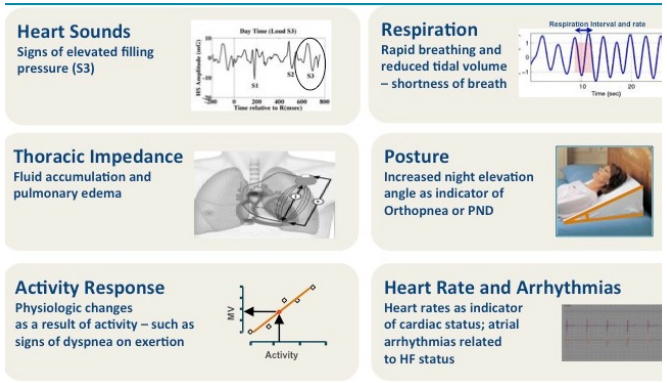


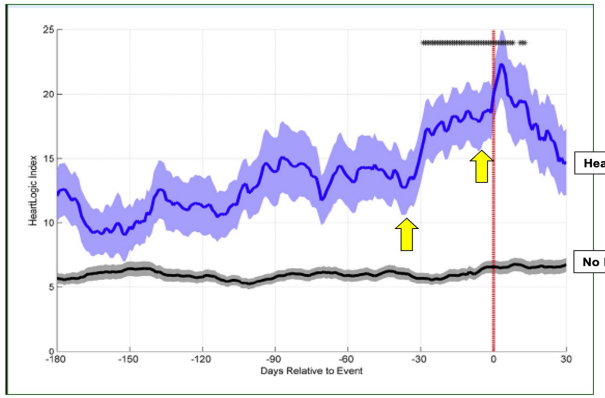
Merchant F / Singh JP. Circulation EP, 2010:3: 357
Abraham WA et al, Lancet 2015

Brugada J / Singh JP et al. European Heart Journal 2017

Implantable Sensors

- risk stratify, predict & prevent (**narrow AI**)





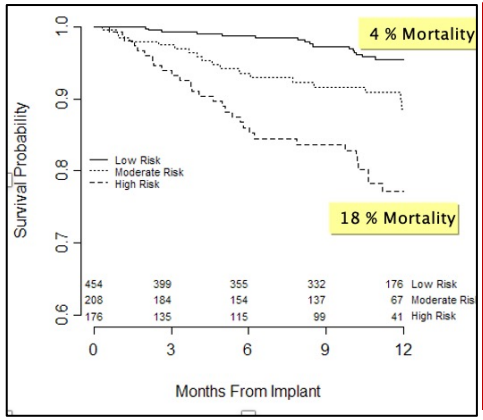
JACC: HEART FAILURE VOL. 5, NO. 3, 2017

ISSN 2213-1779
http://dx.doi.org/10.1016/j.jchf.2016.12.011

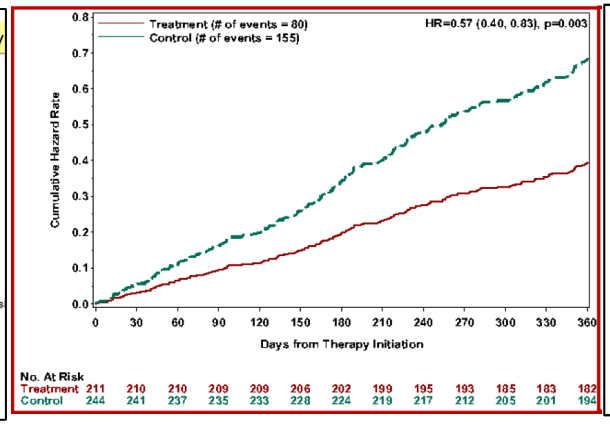
A Multisensor Algorithm Predicts Heart Failure Events in Patients With Implanted Devices

Results From the MultiSENSE Study

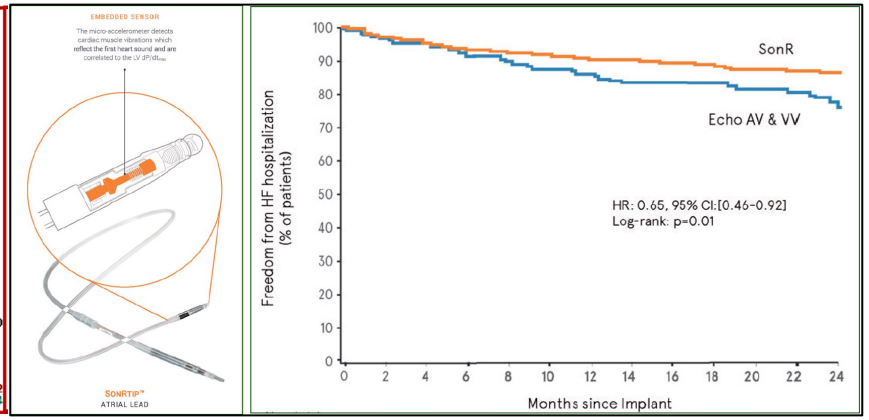
John P. Boehmer, MD,[a] Ramesh Hariharan, MD,[b] Fausto G. Devecchi, MD,[c] Andrew L. Smith, MD,[d] Giulio Molon, MD,[e] Alessandro Capucci, MD,[f] Qi An, PhD,[g] Viktoria Averina, PhD,[g] Craig M. Stolen, PhD,[g] Pramodsingh H. Thakur, PhD,[g] Julie A. Thompson, PhD,[g] Ramesh Wariar, PhD,[g] Yi Zhang, PhD,[g] Jagmeet P. Singh, MD, DPhil[h]



Singh JP et al. Europace 2010

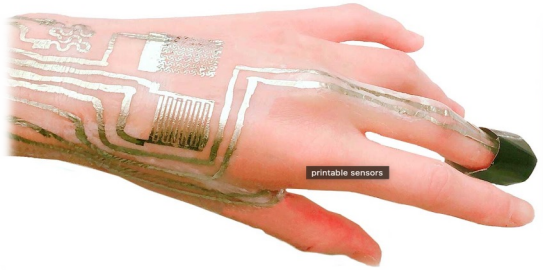


Abraham W/ Singh J et al. J Card Failure 2016



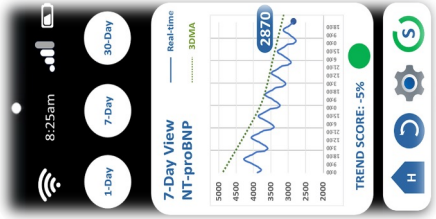
Brugada J / Singh JP et al. European Heart Journal 2017

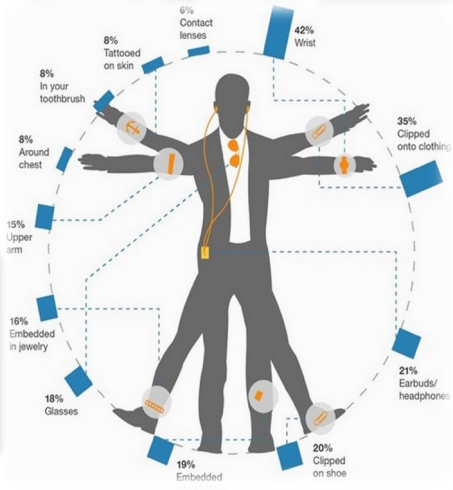
Wearables & Ambient Sensors

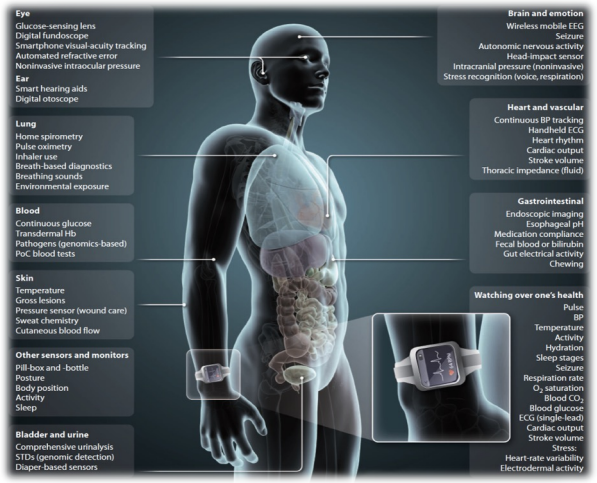


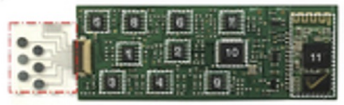
MyDiagnostick Medical B.V.

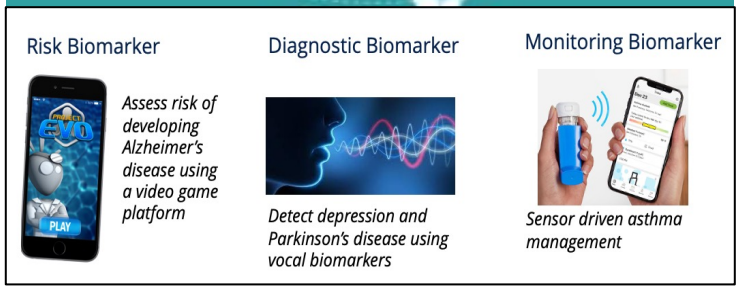
Kardia Mobile and Kardia Mobile 6L - AliveCor®









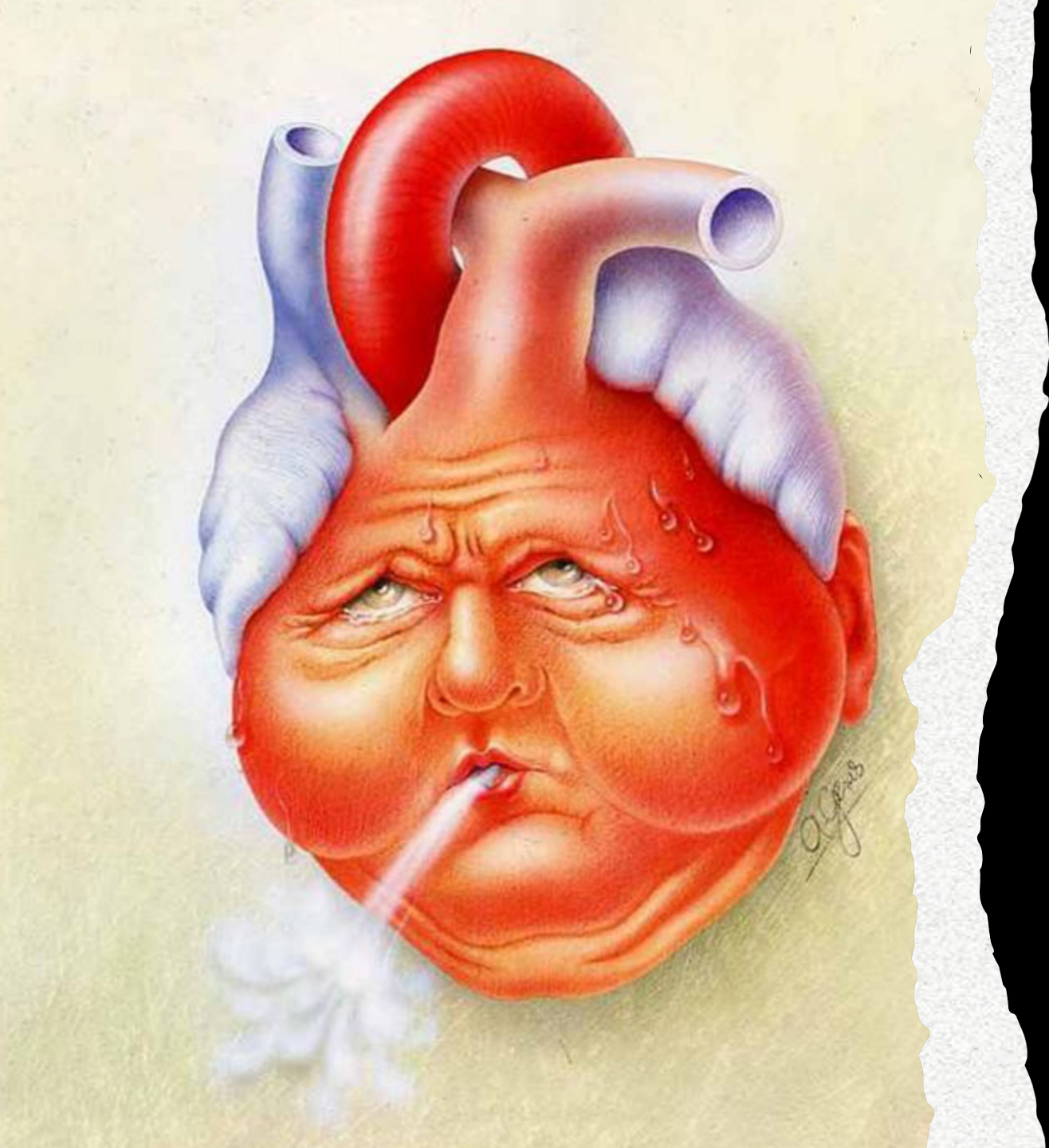


Smartphone revolution

- Numbers are ever-increasing
- Incorporates - medical tool kit

Provides high touch technology

1. Risk, diagnostic & monitoring biomarkers
2. Digital phenotyping of behavioural patterns
3. Monitor Hypertension, Diabetes, HF Parkinson's, asthma, COPD, etc.
4. Predict cognitive decline, Alzheimer's, & HF



Paul's story - II

- Began recovering his heart function (LVEF of 45%)
- Still very brittle, on Hemodialysis
- Multiple admissions in 2005 with Heart failure
- Noted to have atrial fibrillation & NSVT

* No sensor strategies then

Virtual Care – Equitable & Multidisciplinary ?

ESC European Society of Cardiology
European Heart Journal - Digital Health (2021) **2**, 244–253
doi:10.1093/ehjdh/ztab039

ORIGINAL ARTICLE

Social determinants of telemedicine utilization in ambulatory cardiovascular patients during the COVID-19 pandemic

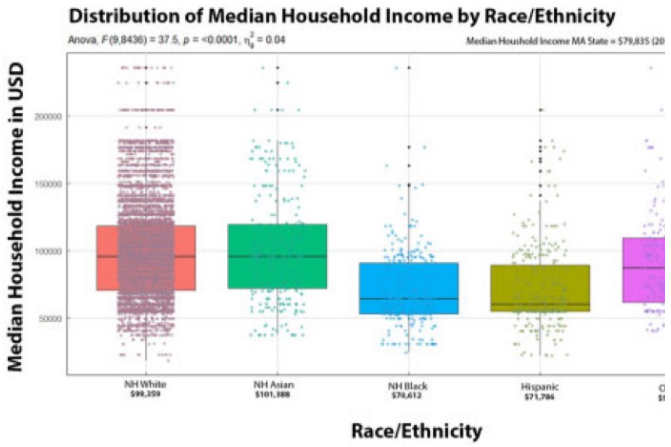
Kemar J. Brown †, Njambi Mathenge†, Daniela Crousillat, Jaclyn Pagliaro, Connor Grady, Nava Katz, Jagmeet P. Singh, and Ami B. Bhatt*

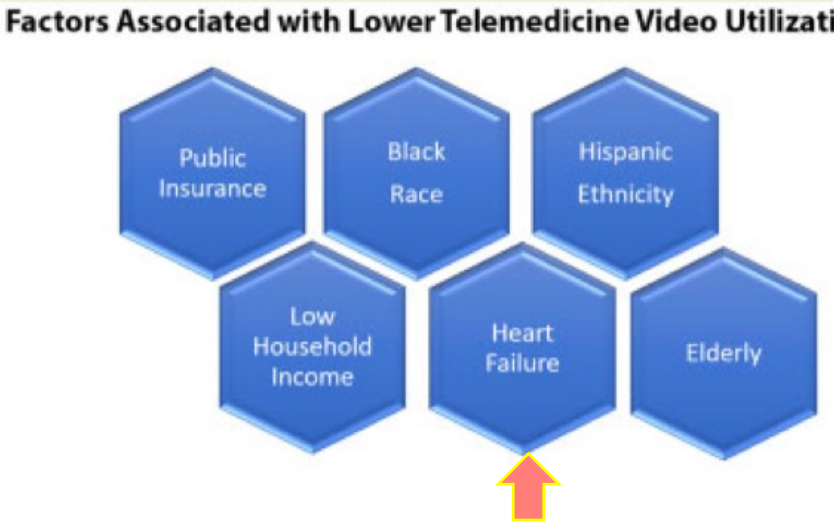
Virtual multidisciplinary care for heart failure patients with cardiac resynchronization therapy devices during the Coronavirus Disease 2019 pandemic

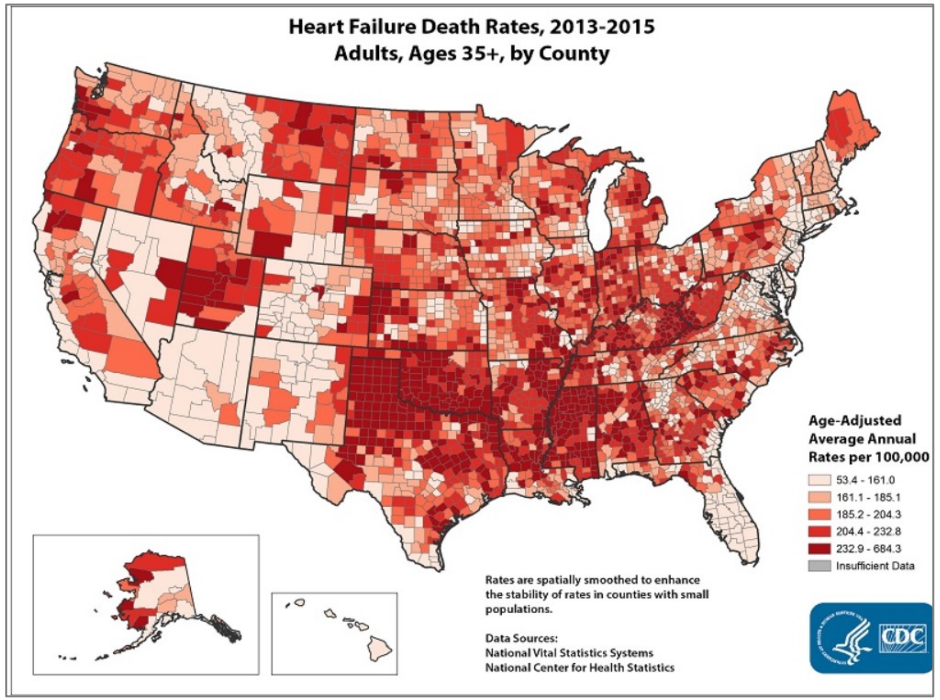
Megan Zhao [a,1], Dingxin Qin [a,1], Gulio Cataldo [a], Krishan Sharma [a], Nupur Dandwate [a], Mary P Orencole [a], Christopher Newton-Cheh [a,b], E. Kevin Heist [a], William J. Hucker [a], Nasrien Ibrahim [a], Jagmeet P Singh [a], Saumya Das [a,*]

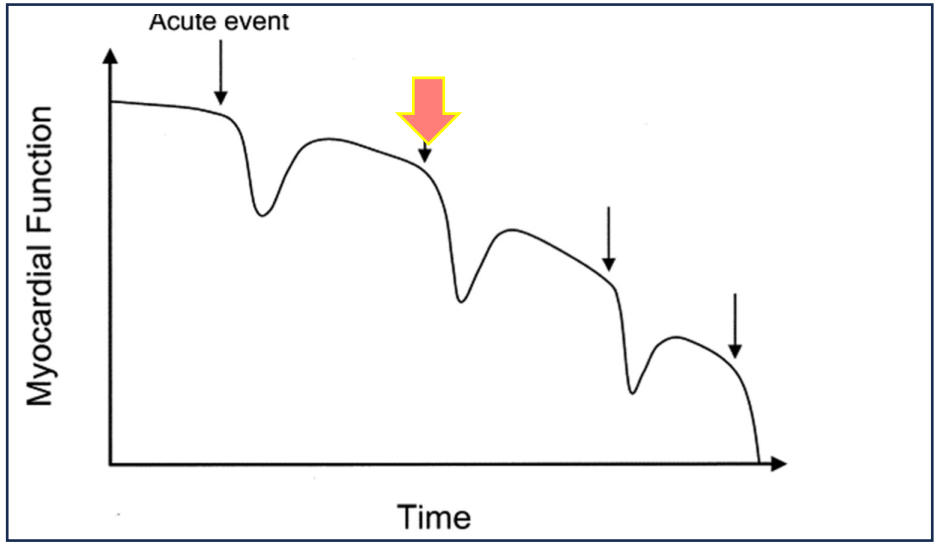
[a] *Cardiovascular Research Center, Harvard Medical School, Massachusetts General Hospital, Boston, MA, United States*
[b] *Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, United States*

IJC Heart & Vasculature 34 (2021)









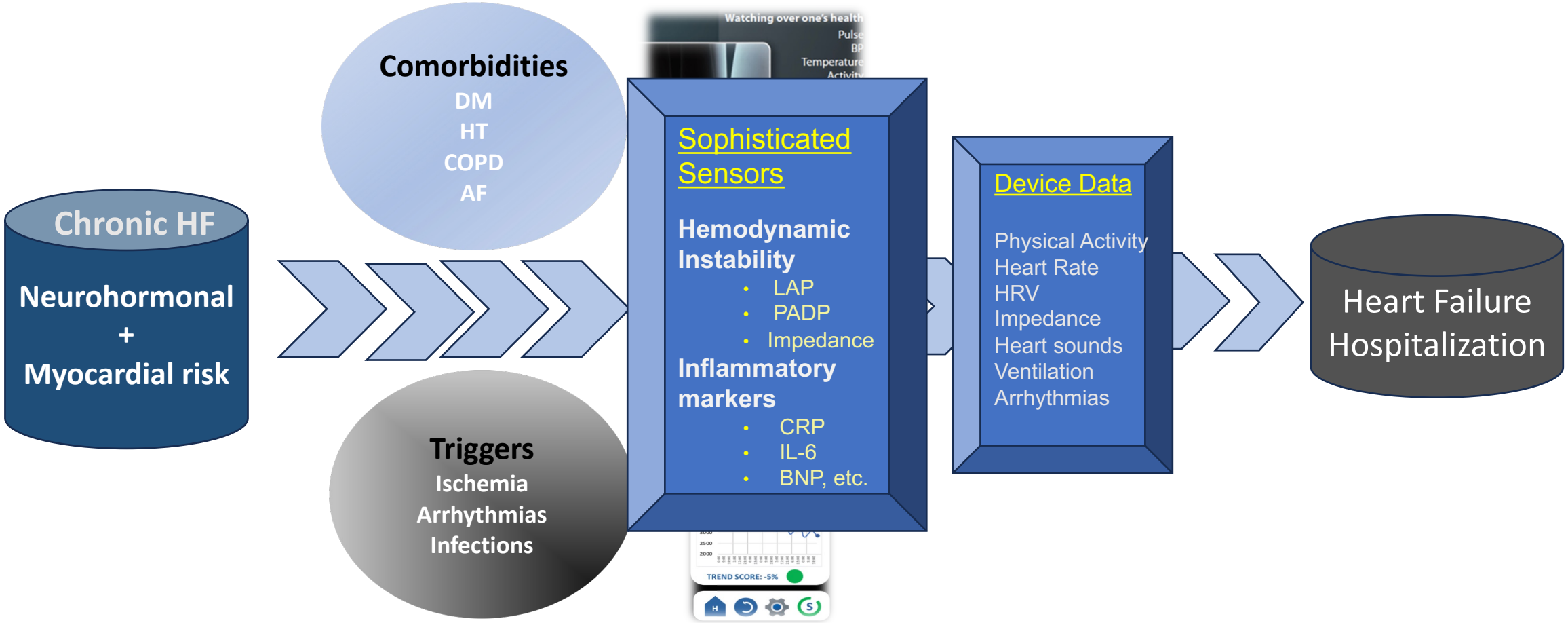
Heart Failure

- Complex problem
- Commonest cause of readmissions
- Projected expenditure – $70 billion by 2030

- Every readmission associated with progressive decline
- But device-based sensors can help us predict & prevent

AI Facilitated-Sensor Data Integration

Predicting & prevention

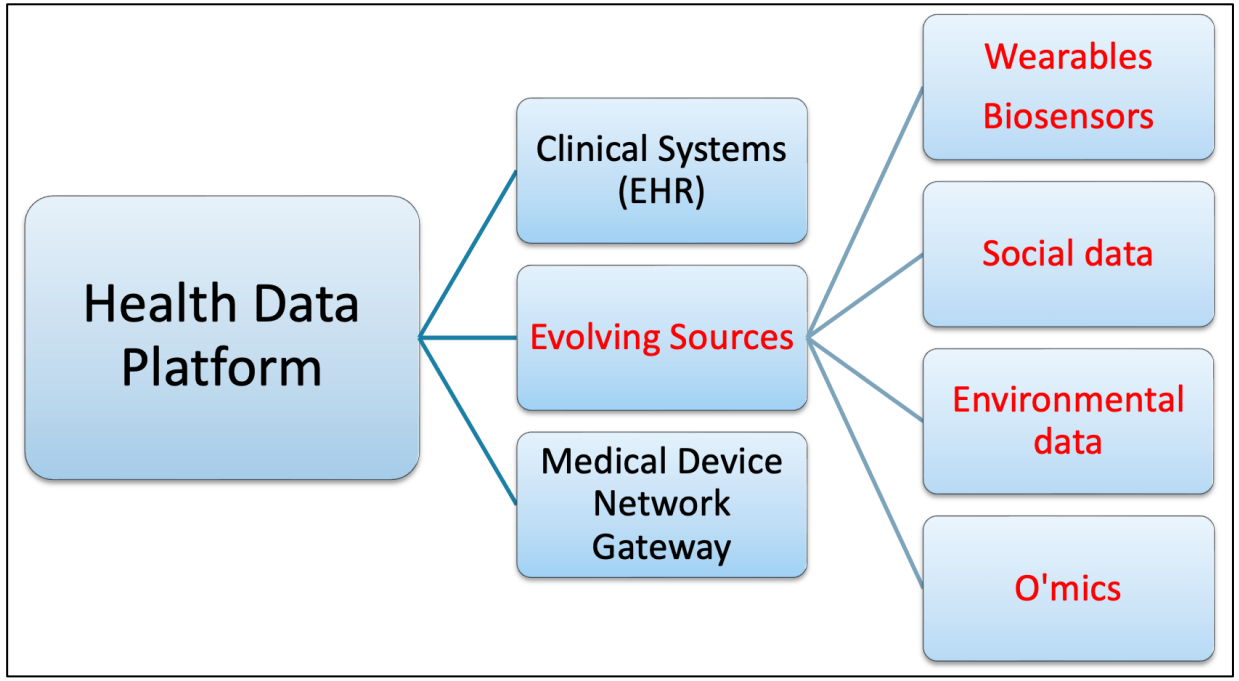


Merchant F / Singh JP. Circulation EP, 2010:3: 357

The Data Conundrum

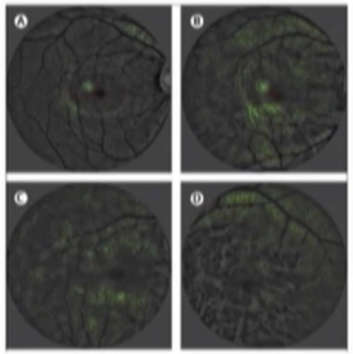
You can have data without information, but you cannot have information without data

Daniel Keys Moran



Machine Eyes vs. Human Eyes (Analytical AI)

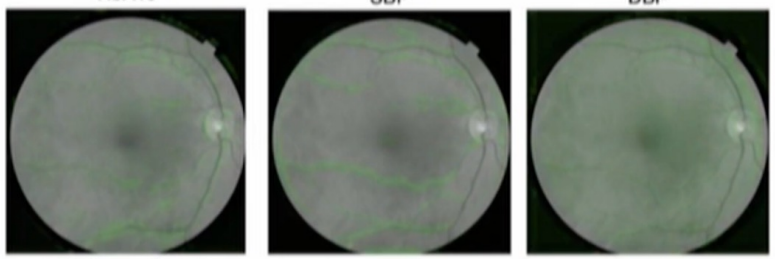
Kidney Disease



A deep learning algorithm to detect chronic kidney disease from retinal photographs in community-based populations

Lancet Digital Health May 12, 2020

Diabetes and Blood Pressure Control



Actual: non-diabetic
Predicted: 6.7%

Actual: 148.5 mmHg
Predicted: 148.0 mmHg

Actual: 78.5 mmHg
Predicted: 86.6 mmHg

Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning

nature biomedical engineering

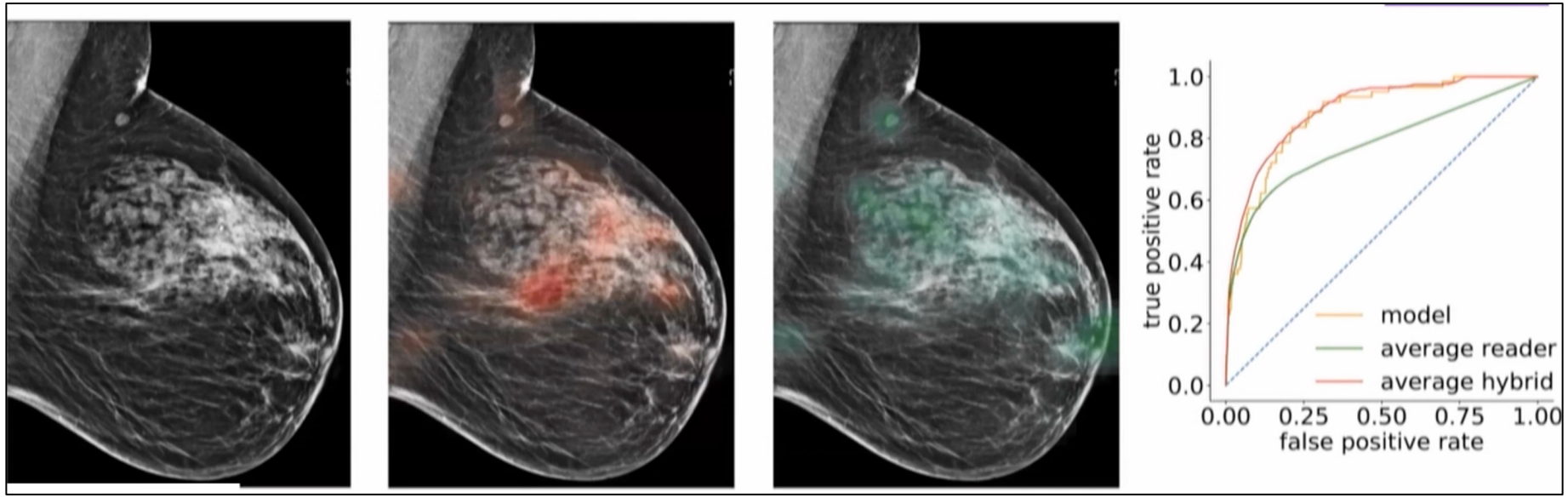
March 2018

Alzheimer's Disease

A system based on AI will scan the retina for signs of Alzheimer's

AlzEye

Moorfields Eye Hospital NHS Foundation Trust



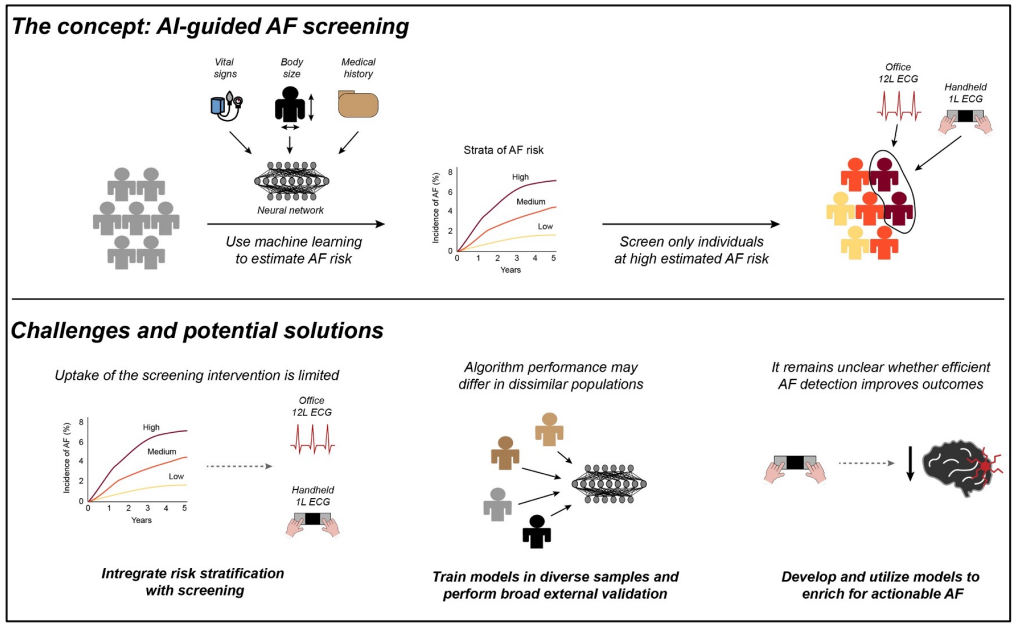
What about Atrial fibrillation ?

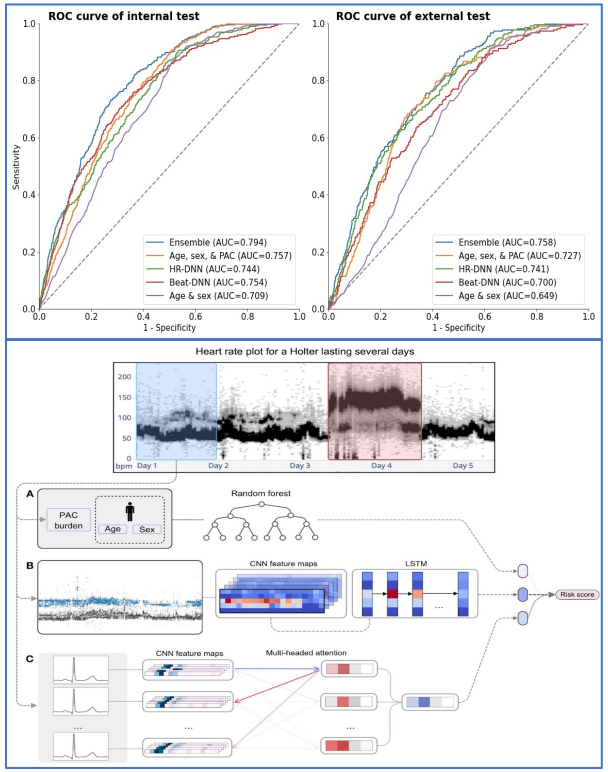
- **Atrial Fibrillation**
  - Prevalence
  - Clinical manifestations
  - Double whammy*
- AI -ECG – can predict AF, SCD, HF, etc.
- Recognizing the Digital divide

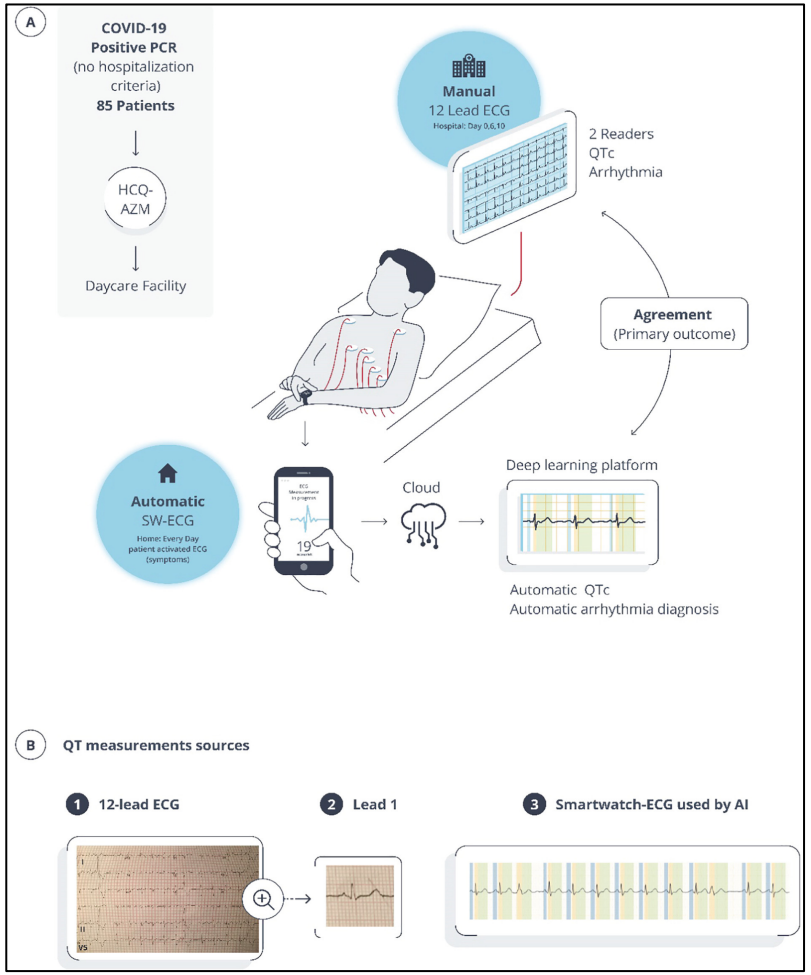
Zinzuwadia A & Singh JP. Lancet Digital 2022 Dec: 4: e856

Managing Atrial Fibrillation

Machine Learning + Sensors + AI-ECG + Cloud based Algorithms







PULsE-AI Study, Hill N et al, EHJ-DH 2022

Khurshid S & Singh JP, EHJ – DH 2022

Zinzuwadia A & Singh JP. Lancet Digital 2022 Dec: 4: e856

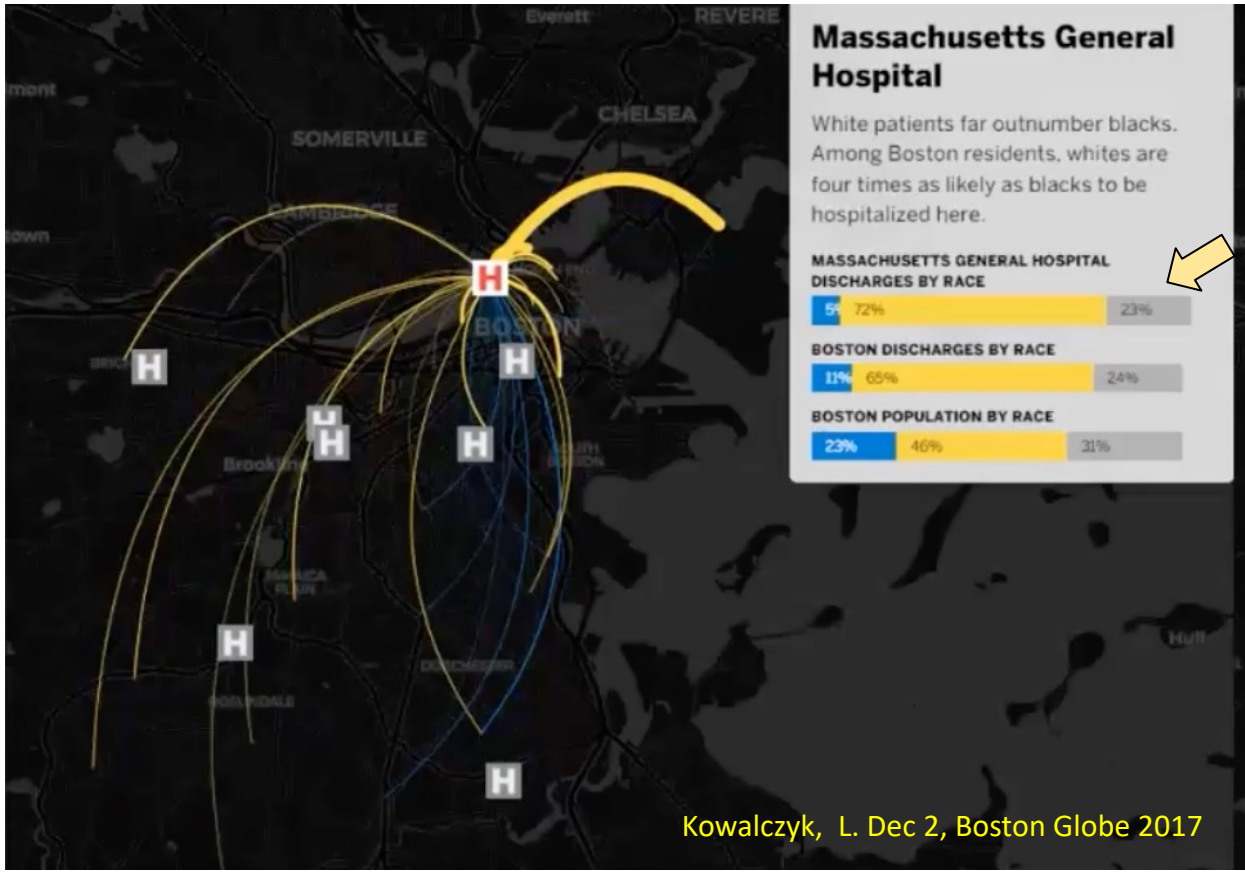
Singh JP et al. Eur Heart Journal- DH, May 2022

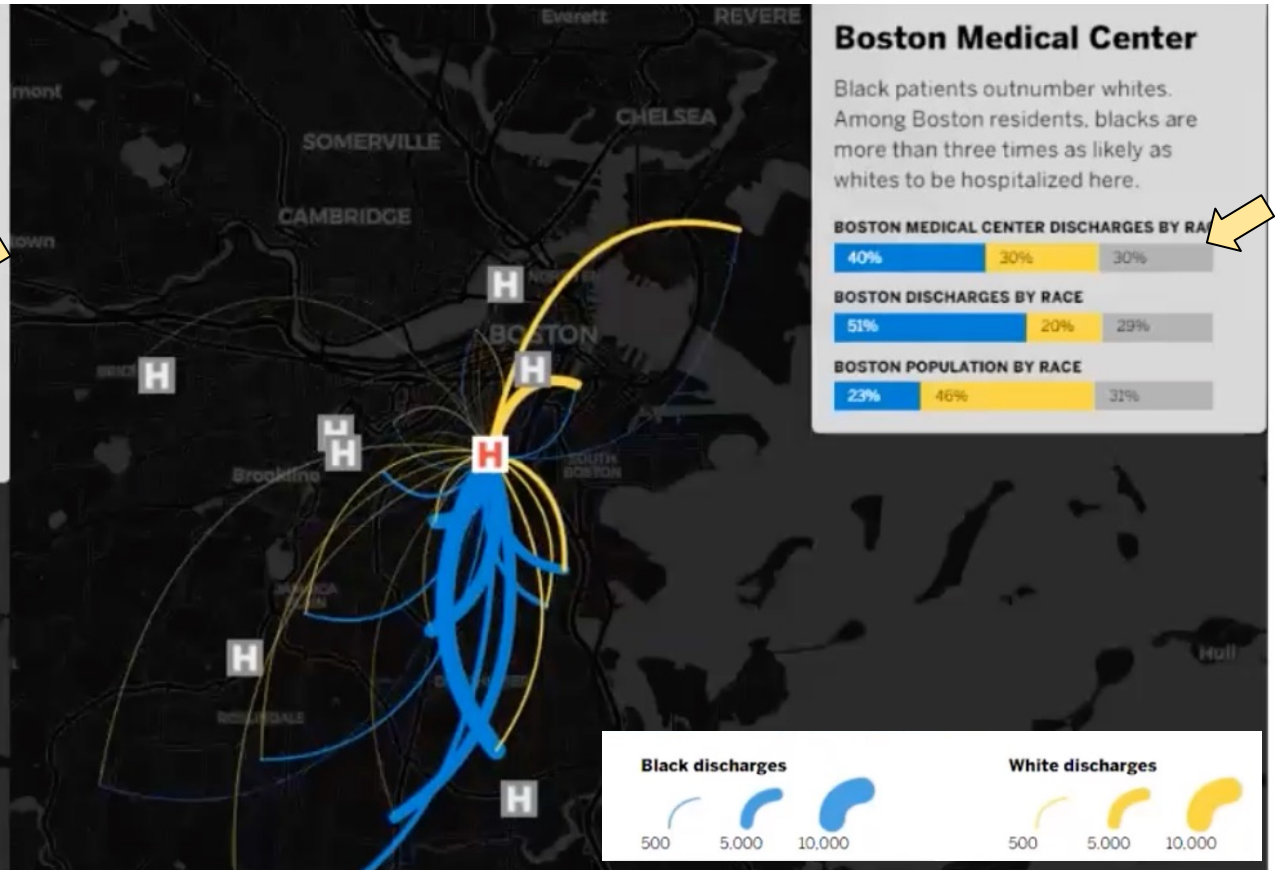
Attia Z et al, Lancet Sept 2019

Maille B / Singh JP et al. *Int J Cardiol*. 2021; 331:333-339

Watch-QT Study (MGH)

Data, Equity & Implications

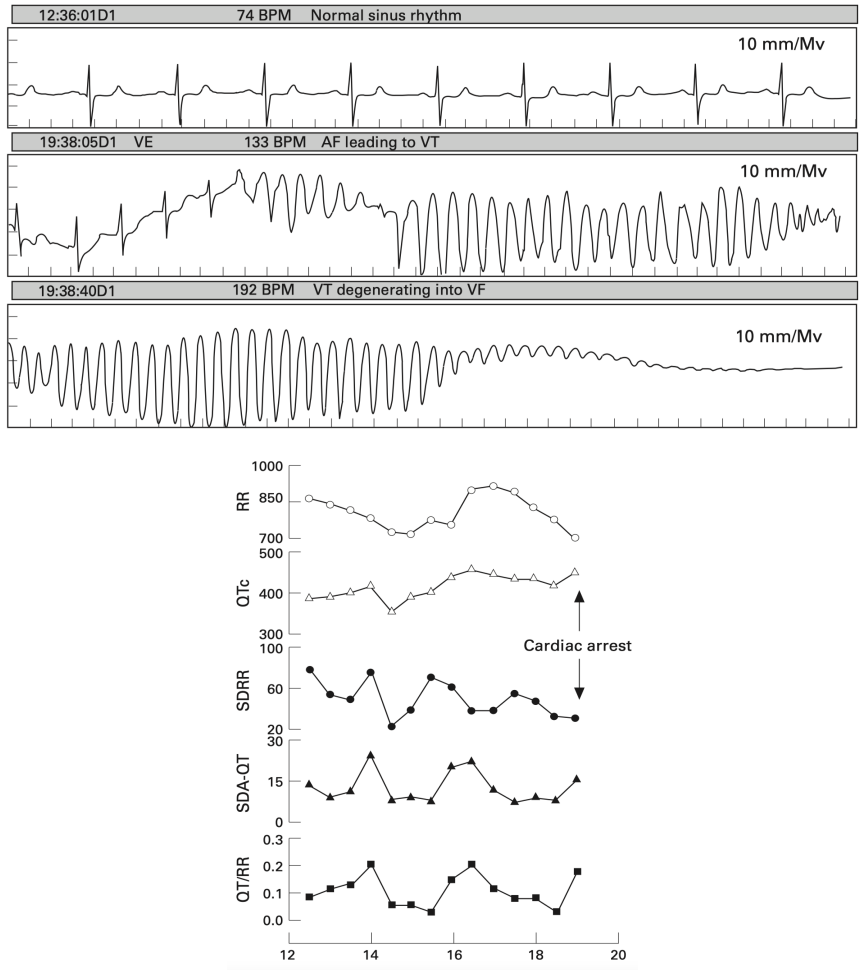




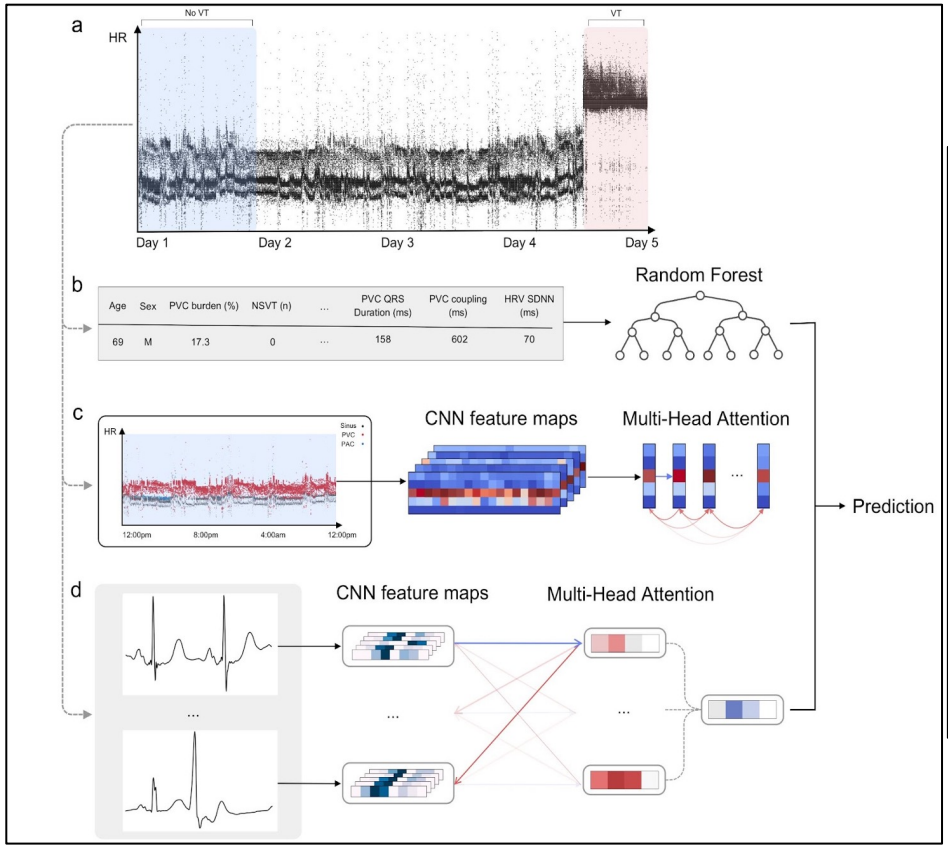
Kowalczyk, L. Dec 2, Boston Globe 2017

Social & Income Inequality → Housing, Diet, Access & Preventive services → Biological Consequences

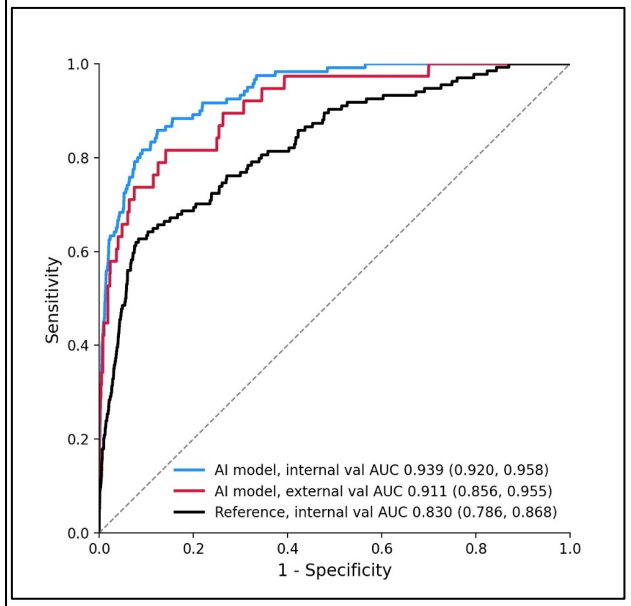
Predicting Ventricular Tachycardia / VF



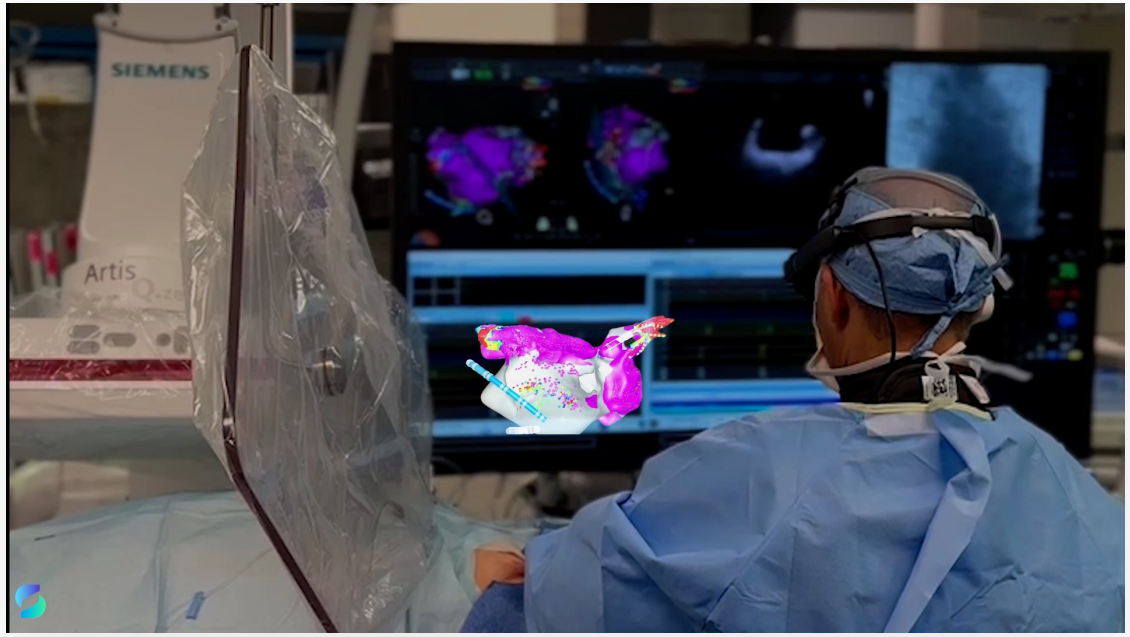
Singh JP, Sleight P, et al. Heart 1997, 77:375

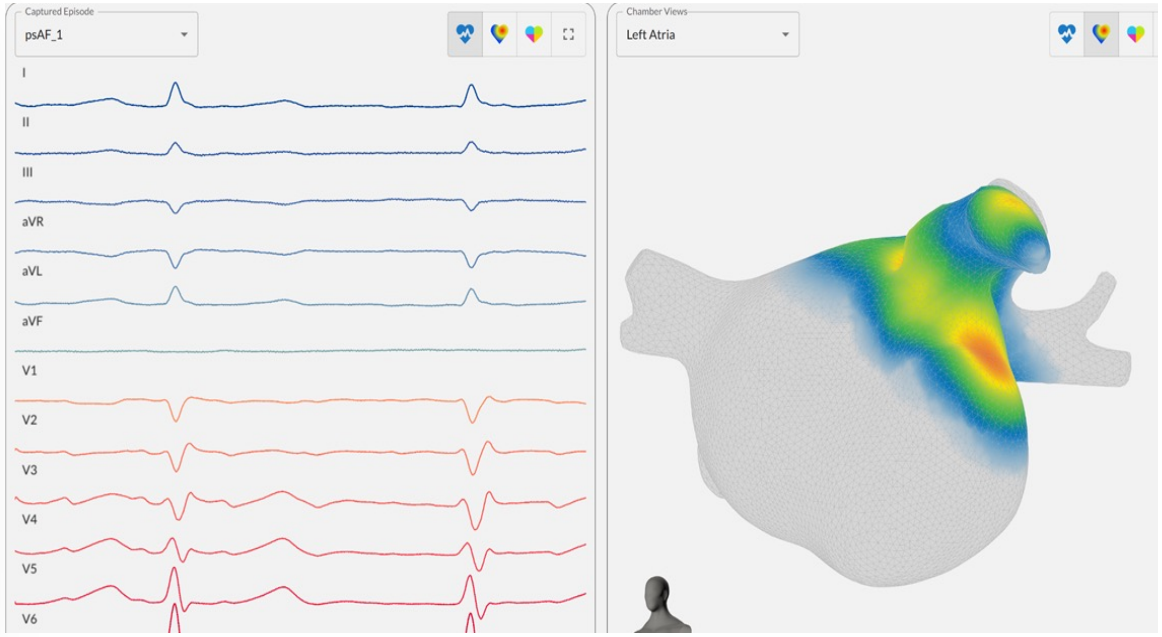


Laurent F, Singh JP, Marijon E, et al Lancet Digital 2024 (in press)



Augmented Reality + AI Facilitated mapping (A-Fib Ablation)





Paradigm AF Study (Singh JP, MGH)

Krummen D et al. V-MAP study. Circulation AE 2021

What about Paul?

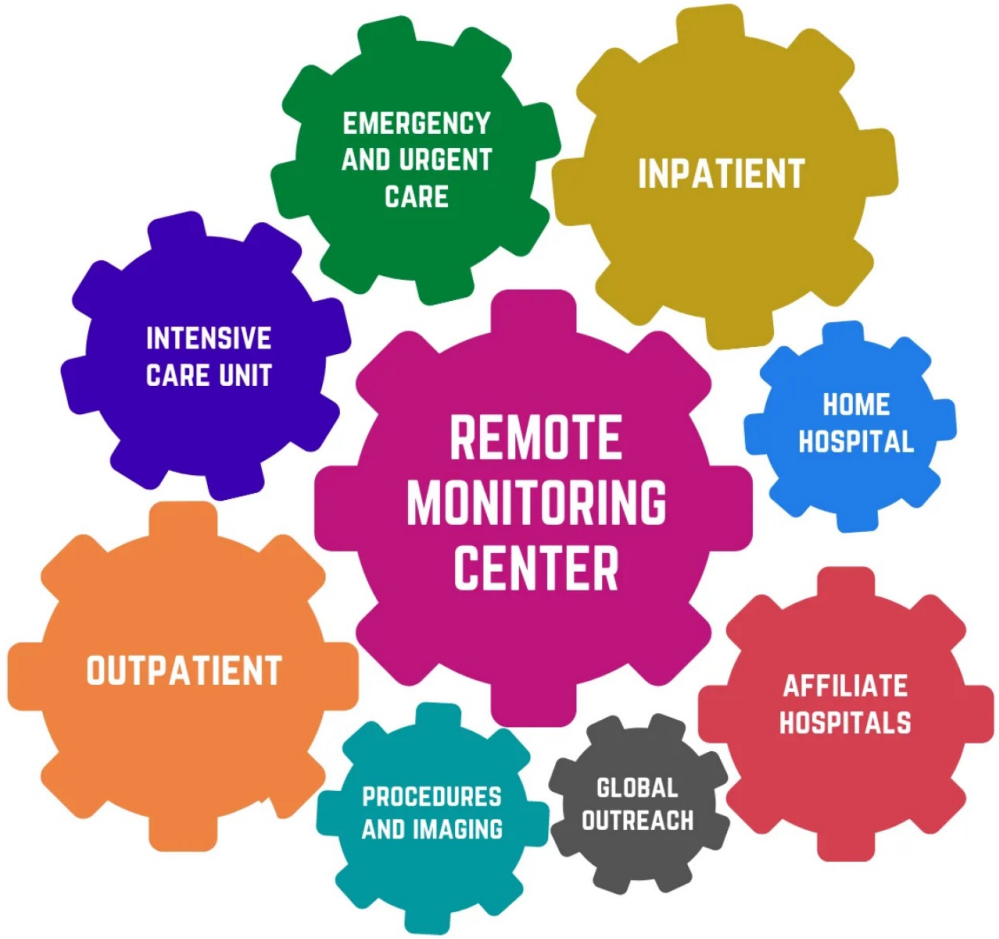
- Chronic diseases were allowed to progress to renal and heart failure
- It was all preventable
- Siloed care – episodic & transactional
- Paul lost many years of his life and his youth dealing with disease & our healthcare system incurred huge expenses!

Fostering the Digital Culture

- Ensuring sustainability & demand for value
- Being Digital is different, from being digitized
- Need to redefine the value proposition
  - Transactional **to continuous care**
    - AI-driven logic
    - Continued evolution of algorithms
    - Exception based care
  - MYOD

Singh JP. J Am Coll Cardiology- Clinical EP 2019
Zhao M, Wasfy J and Singh JP . Lancet Digital 2021

Remote Monitoring & the Future of Care



Singh JP. Medium 2021

- RM - lifecycle of disease
- Synergistic convergence between conventional AI + Generative AI + Clinicians
- Chronic care, Readmissions, self management, etc.

High Priority

i) Peri-operative care
ii) Hospital @ Home – PNA, COPD, chronic disease
iii) Specialty high burden care – HF, AF, DM, etc.

* Enhancing Systemness

NYU Langone Health LLM can predict hospital readmissions

The large language model is still in testing, but the AI tool had a median accuracy score of 77.8% compared to a physician score of 62.8%. The code base is now available to all healthcare organizations.

By Andrea Fox | June 09, 2023 | 03:34 PM

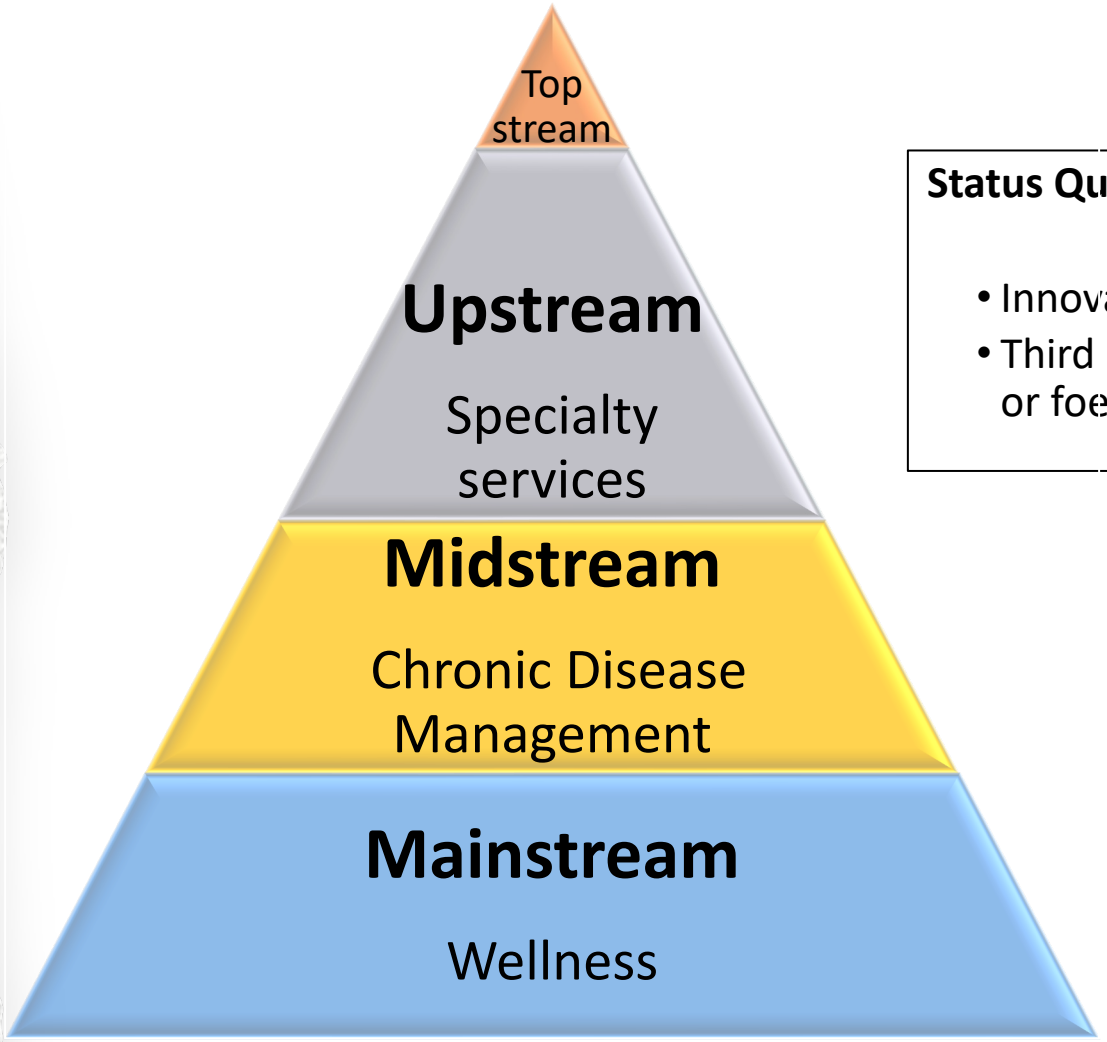
• Chat-GPT & LLM's (Generative AI)

- Decode datasets & write computer programs
- Summarize information
- Will have an assistive role in healthcare
  - Keyboard liberation
    - (ambient notes / draft replies*)
  - burnout
  - clinical decision tools
  - Can predict hospital readmissions

Heart Failure Readmissions

- Narrow AI (via sensors) + conventional AI (ML) + Generative AI
- Self-management approaches

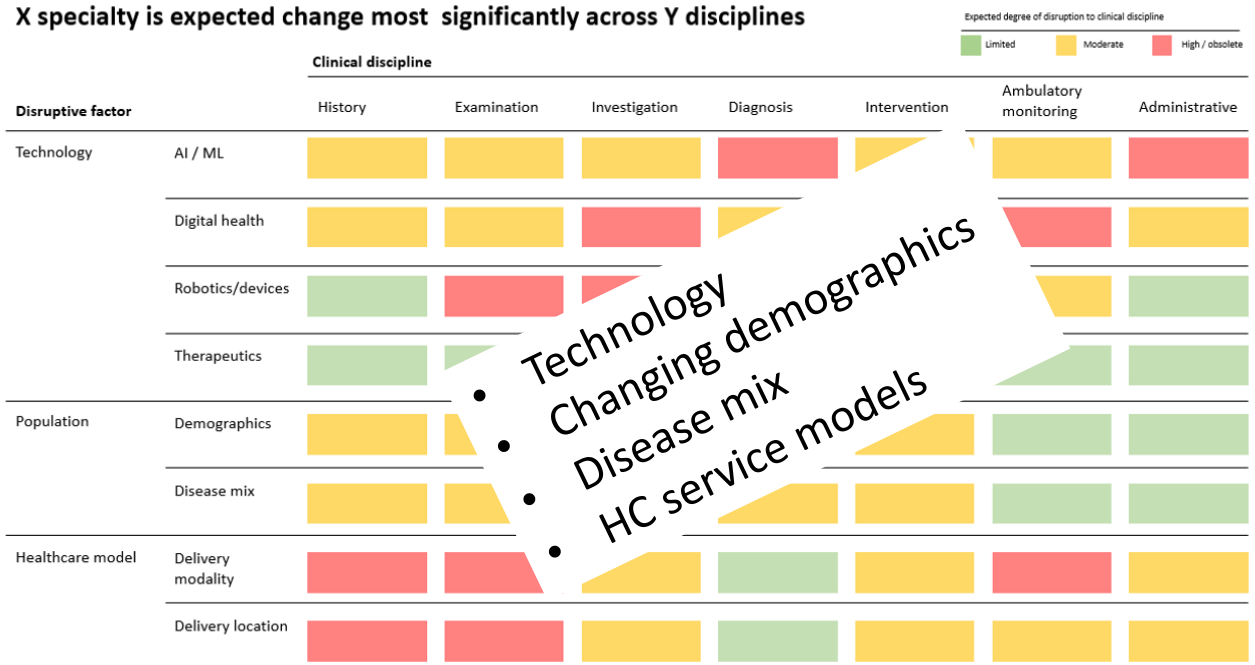
Academic Medical Centers



Status Quo is Untenable

- Innovate & experiment
- Third party vendors – friends or foes?

Disappearing disciplines & Changing Workforce?



Potential future clinical workforce

Role	Up to	Technology (AI/Robots)	Human	
Registered Nurse	40%			60%
Unit Secretaries	50%			50%
Nursing Assistants	30%			70%
Hospitalists	30%			70%
Case Management	50%			50%

AI/ Robotics

Adaptive Workforce (Flexible, remote, or 'gig' workers)

Fixed Workforce

- Pillutla V & Singh JP 2024 (in submission)

Source: Accenture Analysis, 2023

Future models of Care

- Shared savings approach
- Streaming services through 3rd party vendors
  - Disease management models
  - Previvor platforms
- Self management strategies
- Uberization of Healthcare
  - Asset light approaches to out-patient care, research & education across the globe
  - Meeting in the Mediverse
  - Global health equity

Singh JP. Medscape 2023
Singh JP. Medium 2021

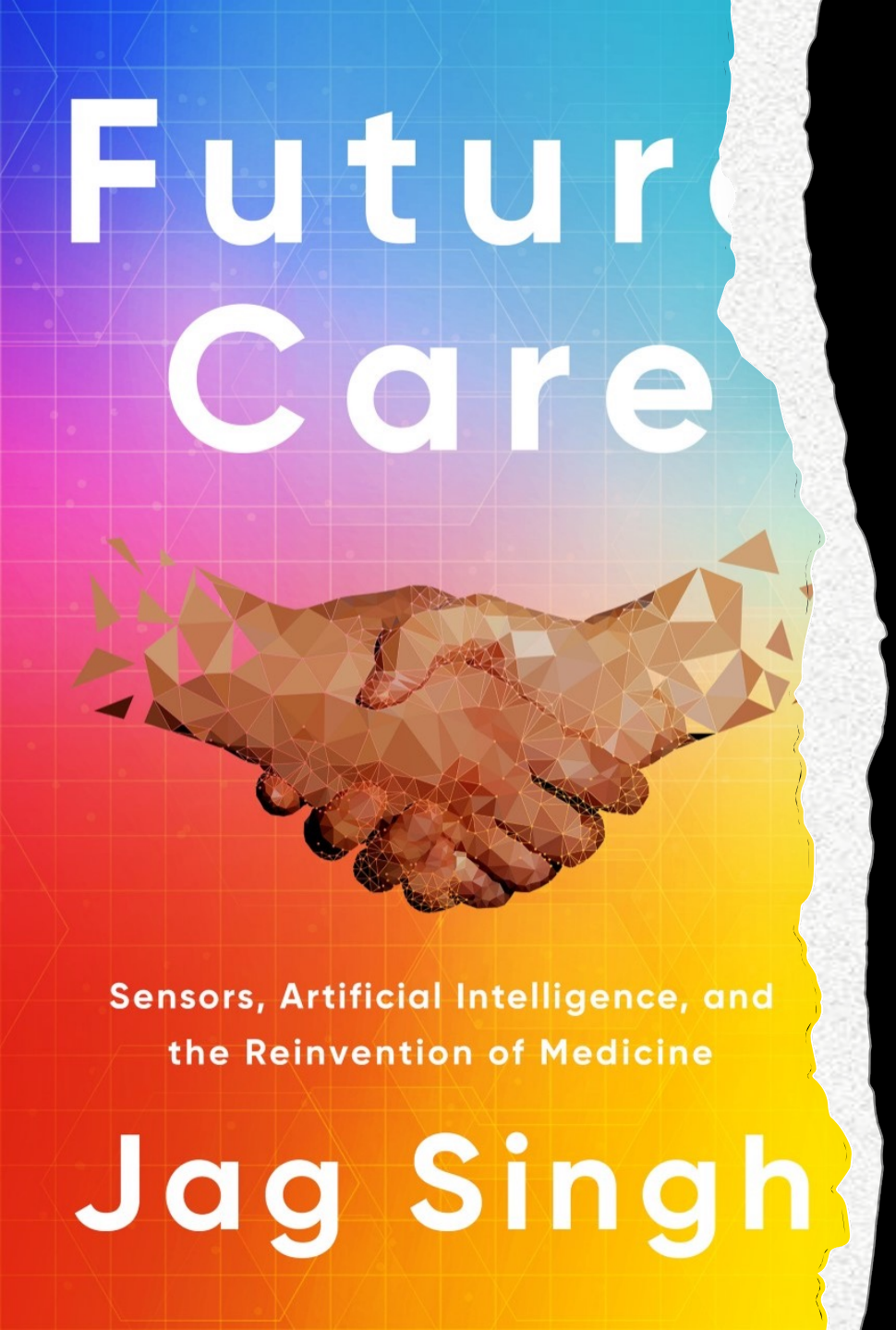
Systemness

- Connected care stratagem
- Initiating construct for the next level of care pathways

Networkness

- Change in the social order of the practice of medicine
- Sensor-aided care with generative AI – across borders
- Evolving framework
- Era of openness with no borders

- Singh JP. Medscape 2022
- Singh JP. Medium 2021



- ‘
- The secret of the **care** of the patient lies in **caring** for the patient’

-Francis Peabody

- Care must always be personal, technology forever tamed & we should continually strive to preserve the human touch!

THANK YOU

@JagSinghMD