Making AI Actionable for Patients with Chronic Disease

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FMC Global Medical Office

November 19, 2019

Agenda

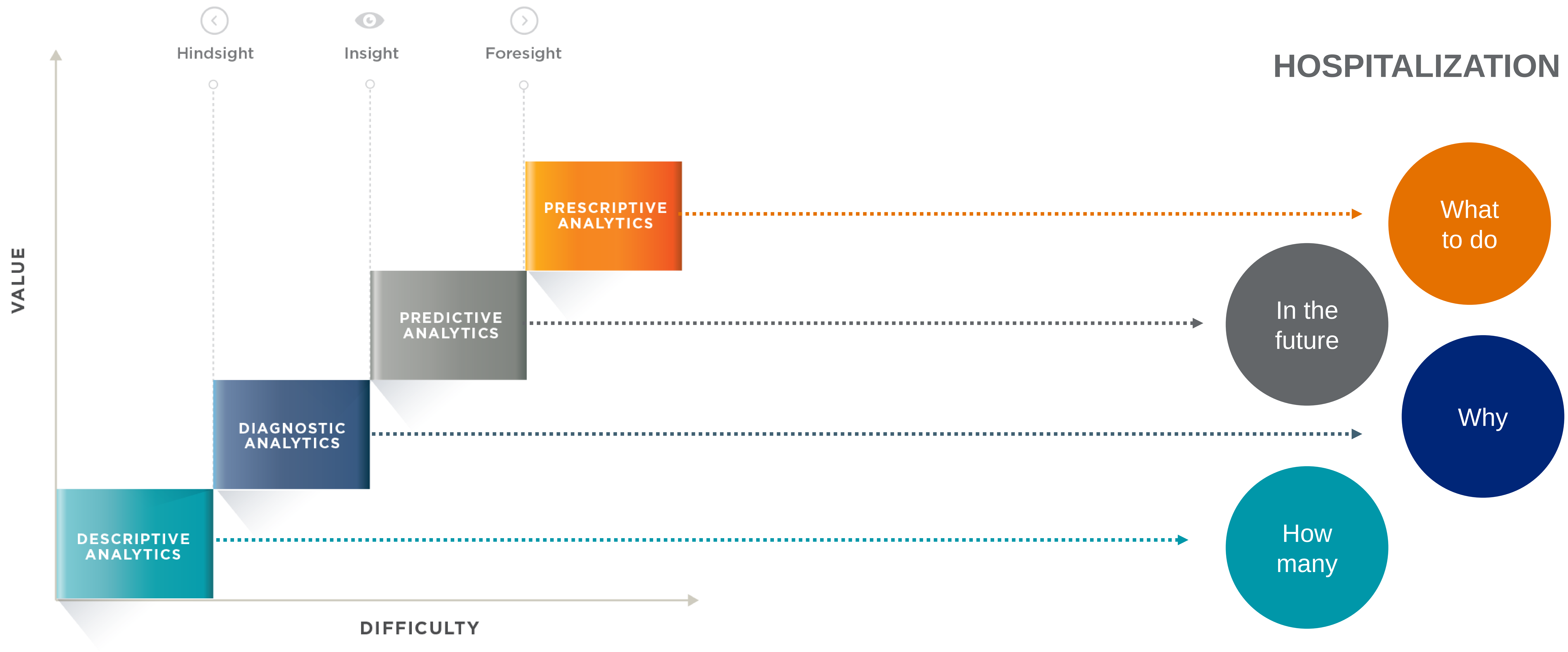
- Analytics and Artificial Intelligence
- About Fresenius Medical Care
- Fresenius Medical Care and Data
- Advanced Analytics: Our Approach
- Portfolio of Existing Efforts
- Future of AI in Healthcare

Analytics and Artificial Intelligence

TRADITIONAL ANALYTICS

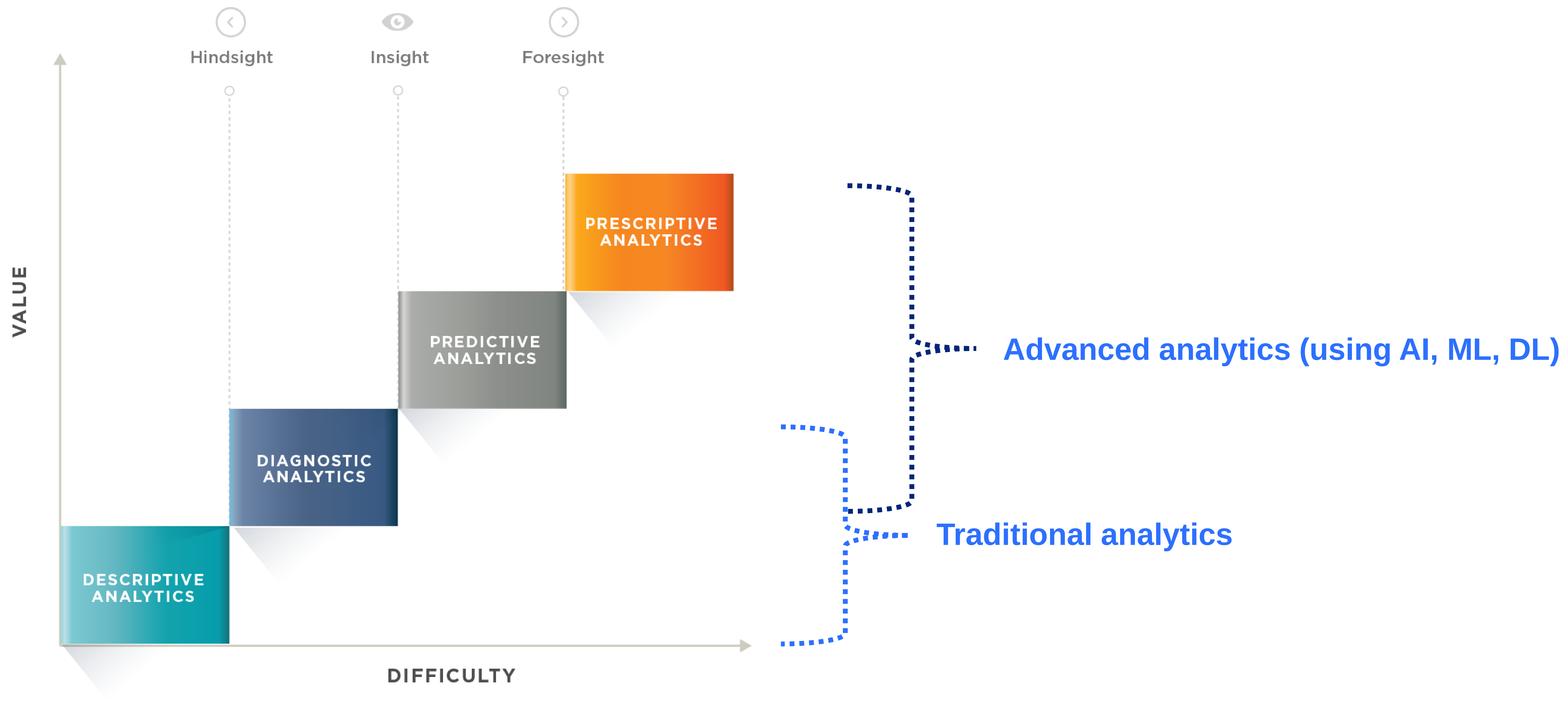
Event prediction
Treatment aid
Condition diagnosis
Mathematical modeling and algorithms

Analytics



Hindsight
Insight
Foresight
VALUE
DIFFICULTY
PRESCRIPTIVE ANALYTICS
PREDICTIVE ANALYTICS
DIAGNOSTIC ANALYTICS
DESCRIPTIVE ANALYTICS
HOSPITALIZATION
What to do
In the future
Why
How many

Analytics

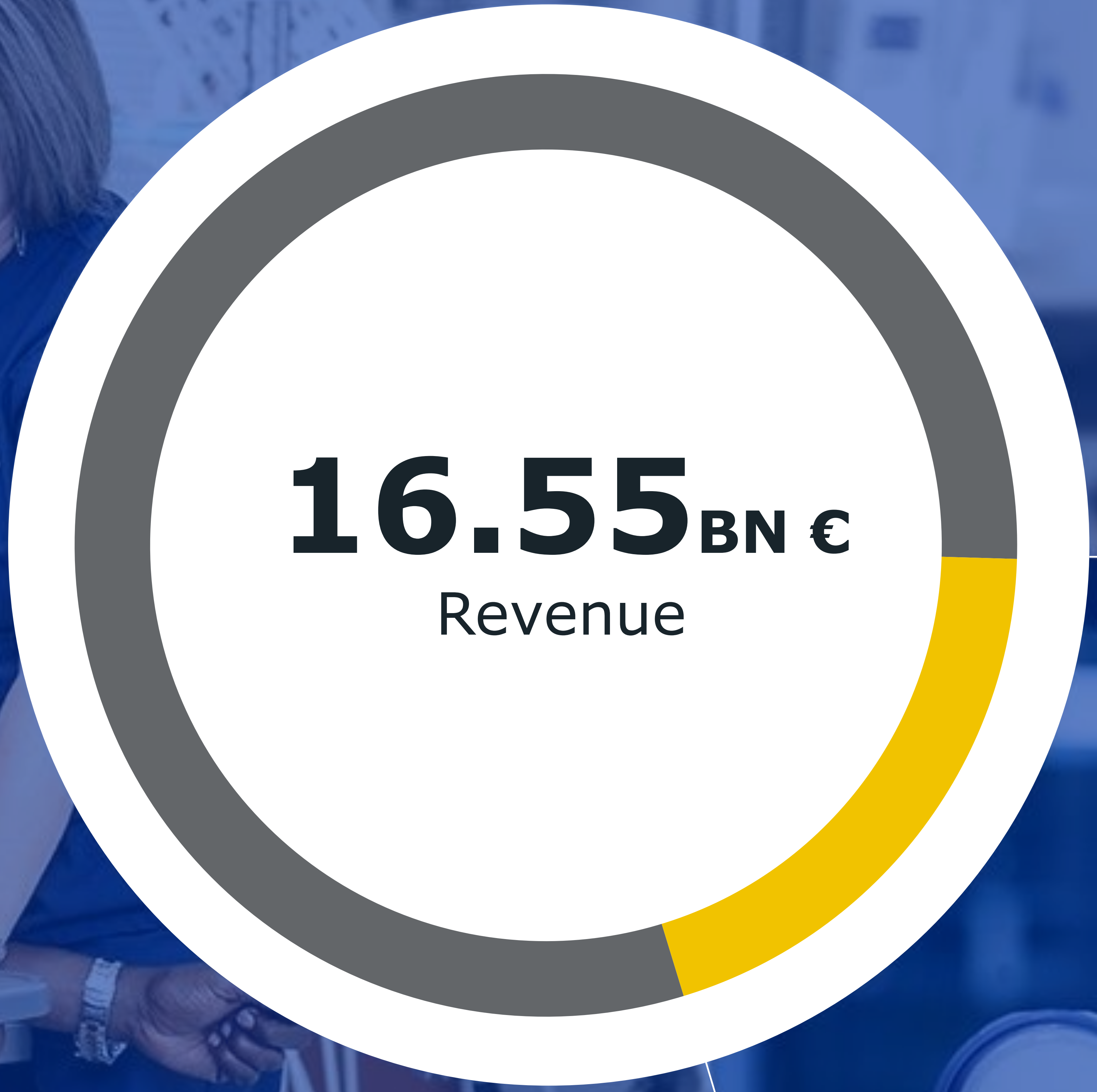

Hindsight
Insight
Foresight
VALUE
DIFFICULTY
DESCRIPTIVE ANALYTICS
DIAGNOSTIC ANALYTICS
PREDICTIVE ANALYTICS
PRESCRIPTIVE ANALYTICS
Advanced analytics (using AI, ML, DL)
Traditional analytics

Fresenius Medical Care

Fresenius Medical Care Portfolio

Health care services

13.27 BN €
of total revenue



Health care products

3.28 BN €
of total revenue

FRESENIUS MEDICAL CARE

We Offer Dialysis Products

#1

supplier of dialysis products

Products for **hemodialysis**, **peritoneal** dialysis, **acute** dialysis, **liver support** and **therapeutic apheresis**, e.g.:

- Dialysis machines, dialyzer
- Bloodline systems
- Concentrates
- Water technology
- PD products

Dialyzers:

- Market share: **~50%**
- **~165** M dialyzer produced in 2018

Dialysis machines:

- Market share: **>50%**
- **50,000** dialysis machines sold in 2018
- **1 of 2** dialysis machines worldwide is made by Fresenius Medical Care

42

producti on sites

We Provide Dialysis Services

- **3,928** own dialysis centers
- Around **50 M** dialysis treatments in 2018
- In around **50** countries
- Market share: **10%** worldwide
- U.S. **38%** (patients treated)

Every **0.6 seconds** we provide a **dialysis treatment**

We Coordinate Care

Patients benefit from our **value-based care approach**

CARE COORDINATION

Driven by our **holistic patient-centric approach** we add relevant services and therapies to our offerings.

Focus: Connected business with high relevance of shared services and patient data

GOALS

- Increase accessibility and high quality, integrated care for our patients
- Actively manage cost of chronically ill patients
- Gaining transparency to enable patient risk management
- Continuously optimize our portfolio of services

FMC and Data

FMC Global Data

Patients

1,914,459

HD Treatments

503,160,902

Labs

1,707,684,229

Comorbidities

33,312,903

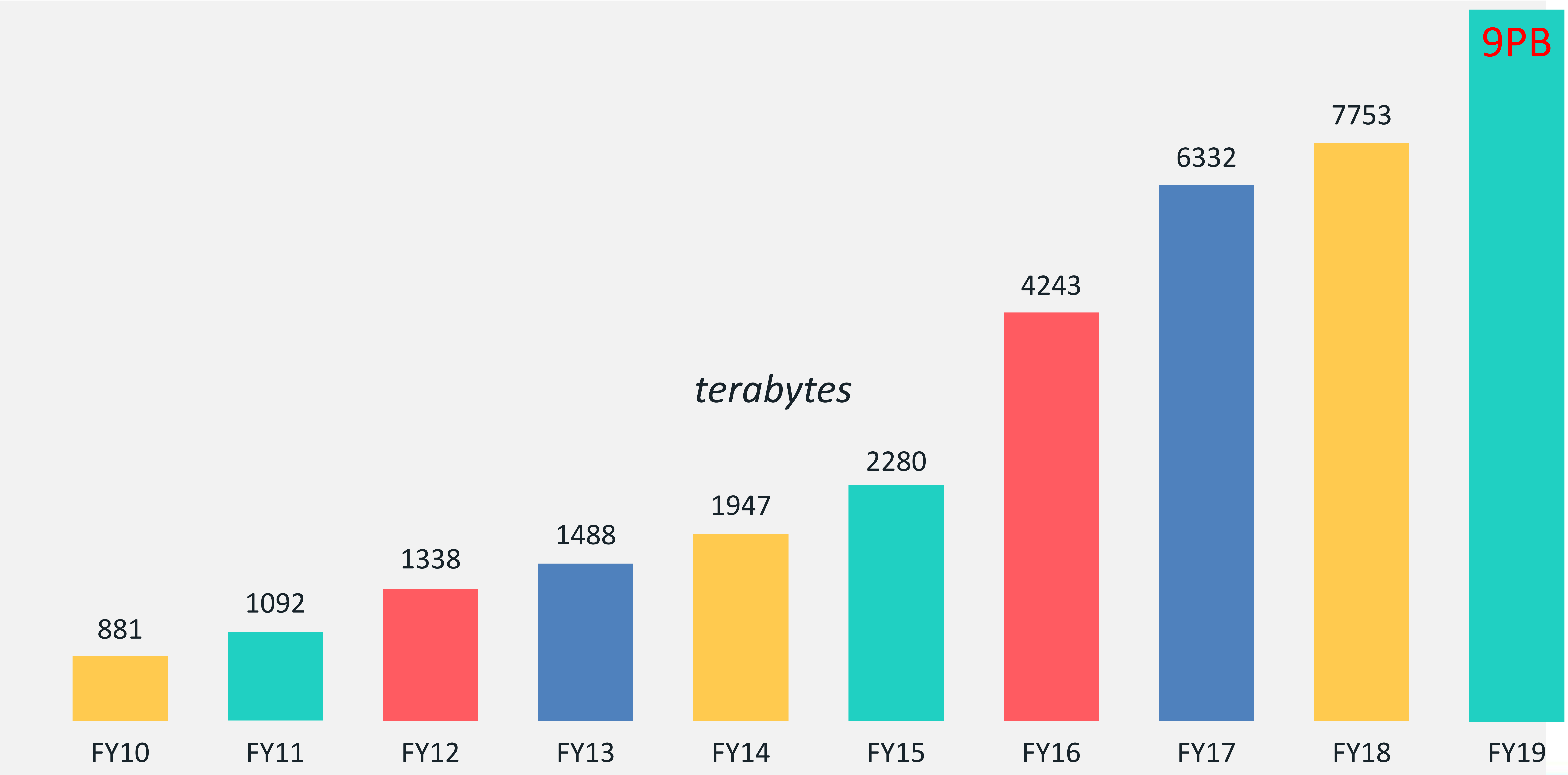
In-Center Medications

1,367,829,509

Home Medications

2,600,344,319

FMC North America Data Storage



Advanced Analytics: Our Approach

Applied Advanced Analytical Process

1 Assessment of modeling demand

2 **TECHNICAL** Model prioritization through A^2 Steering Committee

EXECUTIVE Model prioritization through A^2 Steering Committee

3 Creation of advanced algorithms

4 Piloting and testing of algorithms

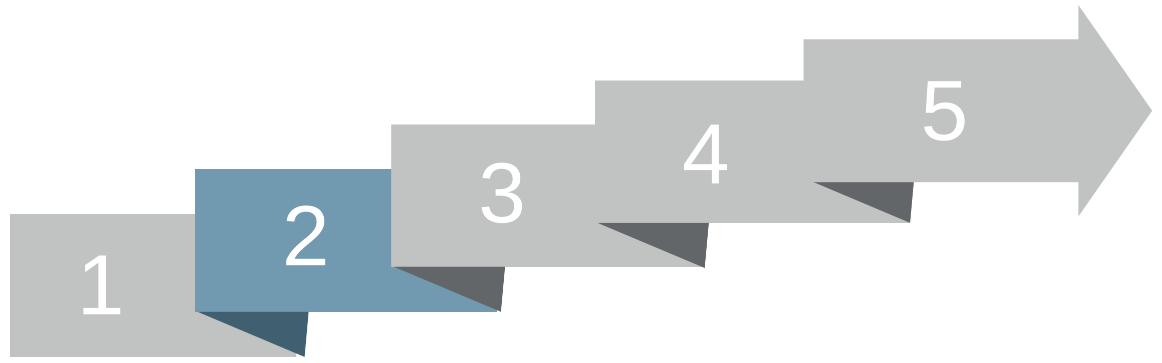
5 Operational rollout and measure outcomes

Assessment of Demand

Listening to organizational needs

Pragmatic approach to advanced analytics

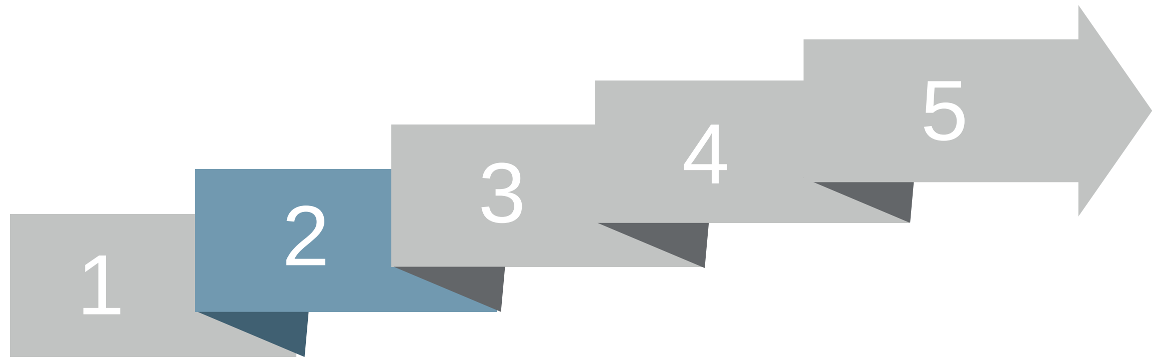
Technical & Executive Steering Committee



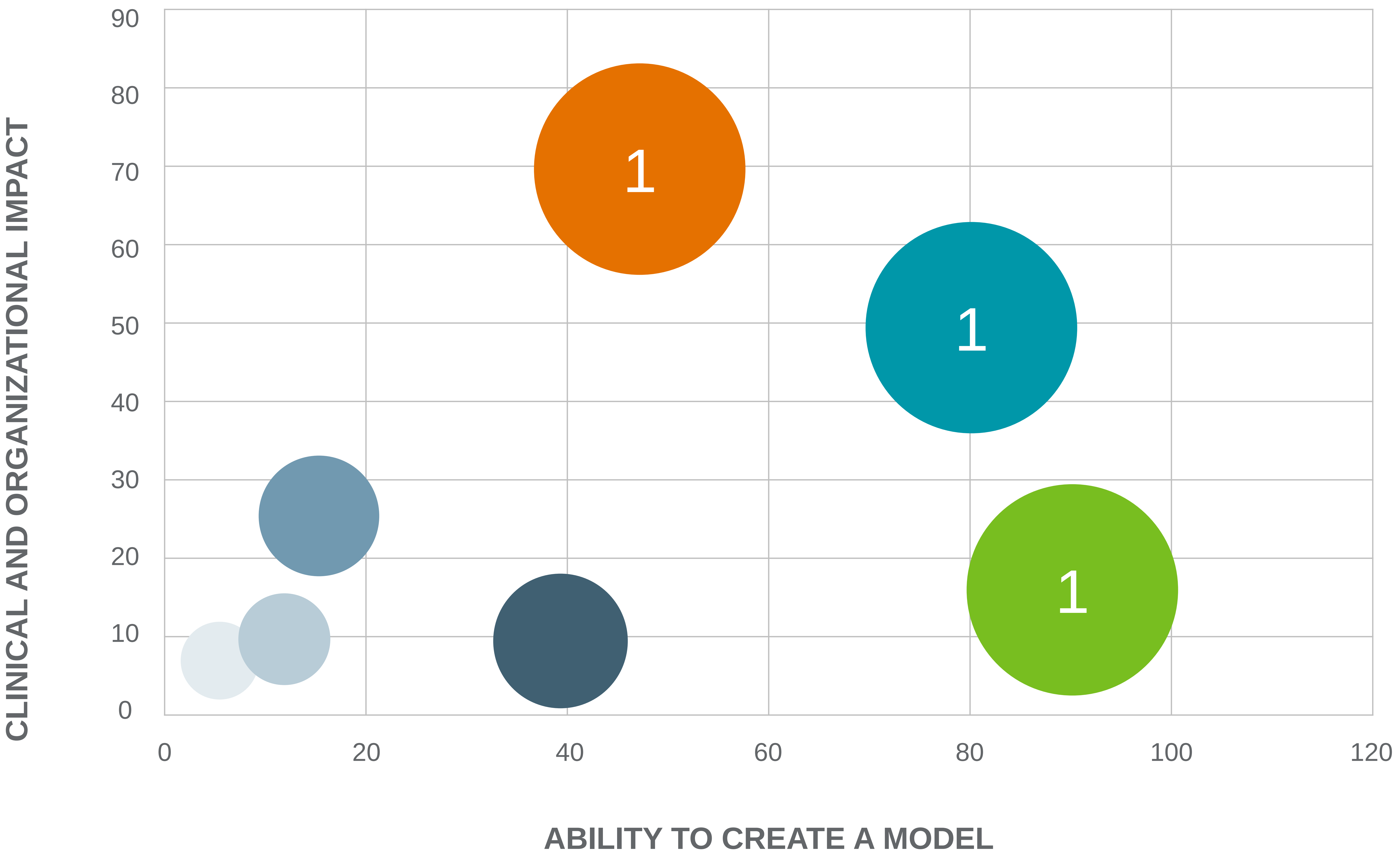
- Executive Members
  - Business leads from:
  - FKC In-Center group
  - FKC Home group
  - FHP
  - FreseniusRx
  - AVC
- Global R&D

- Technical Members
  - Medical leads
  - Business leads
  - Operational leads
  - IT
  - Data Scientists

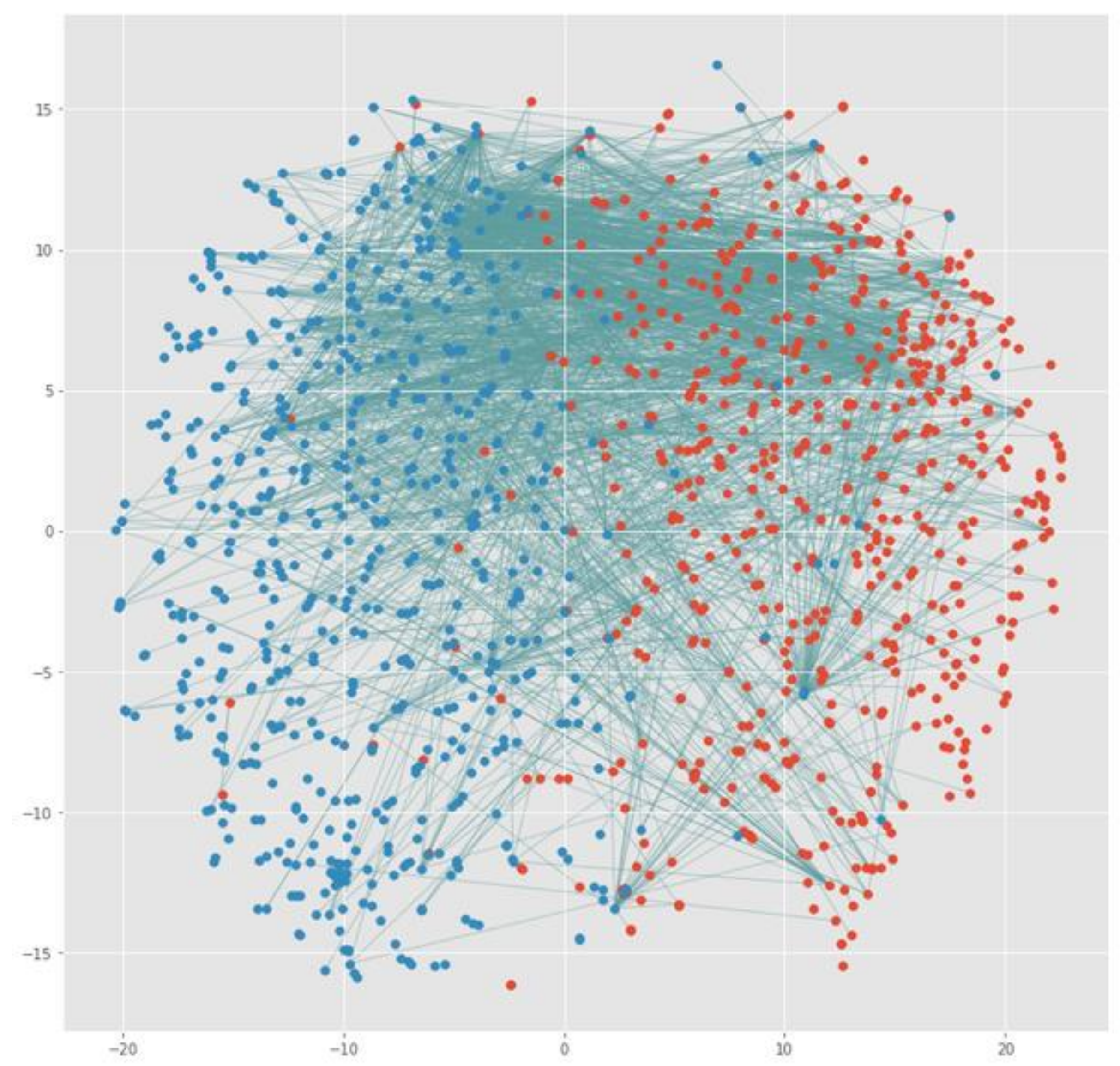
Prioritization Process



How it Works



Creation of Models



1. Initialize model with a constant value:

$$F_0(x) = \arg\min_{\gamma} \sum_{i=1}^{n} L(y_i, \gamma).$$

2. For m = 1 to M:
   1. Compute so-called *pseudo-residuals*:

   $$r_{im} = -\left[\frac{\partial L(y_i, F(x_i))}{\partial F(x_i)}\right]_{F(x)=F_{m-1}(x)} \quad \text{for } i = 1, \ldots, n.$$

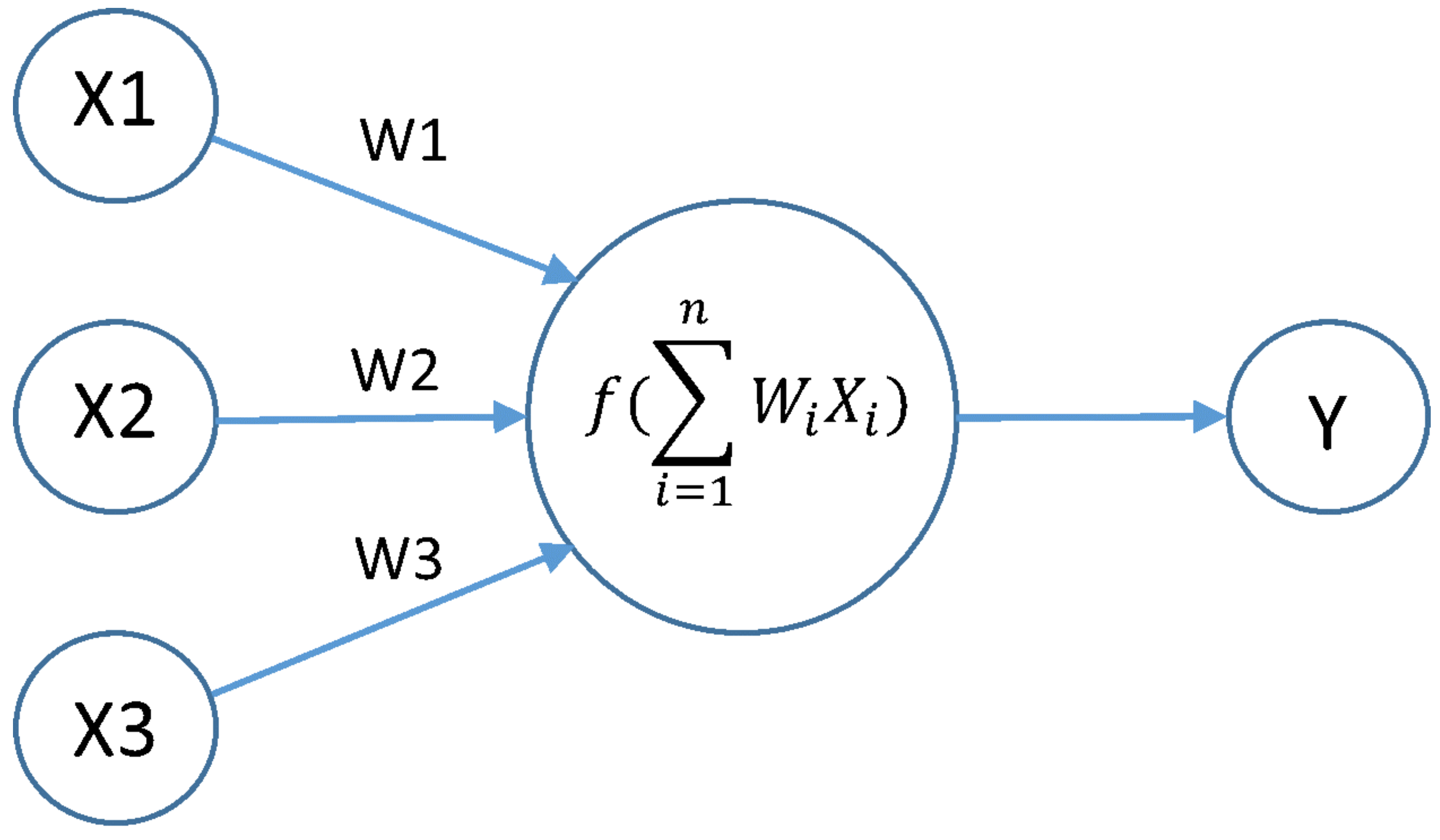
   2. Fit a base learner $h_m(x)$ to pseudo-residuals, i.e. train it using the training set $\{(x_i, r_{im})\}_{i=1}^{n}$
   3. Compute multiplier γ_m by solving the following one-dimensional optimization problem:

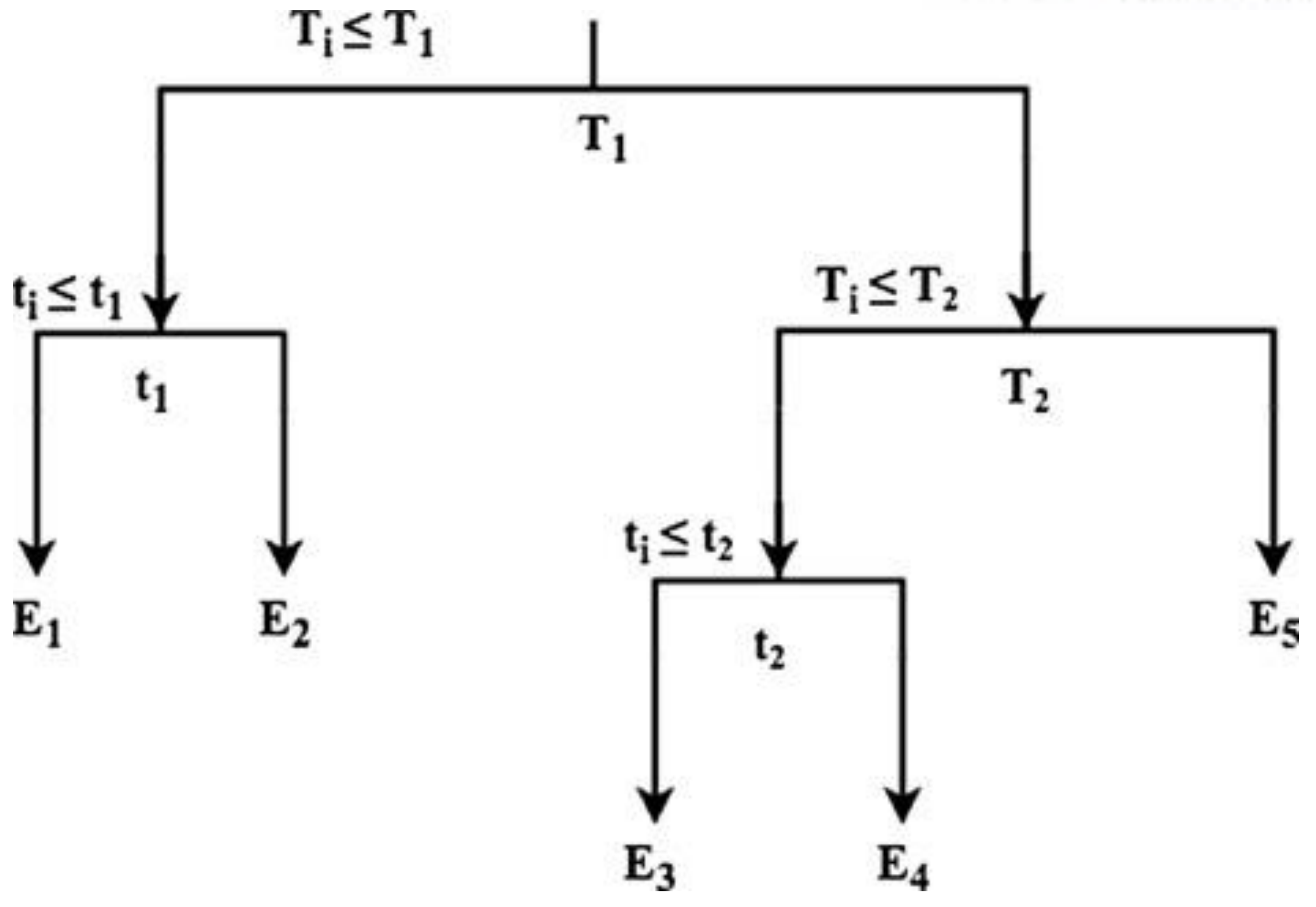
   $$\gamma_m = \arg\min_{\gamma} \sum_{i=1}^{n} L\left(y_i, F_{m-1}(x_i) + \gamma h_m(x_i)\right).$$

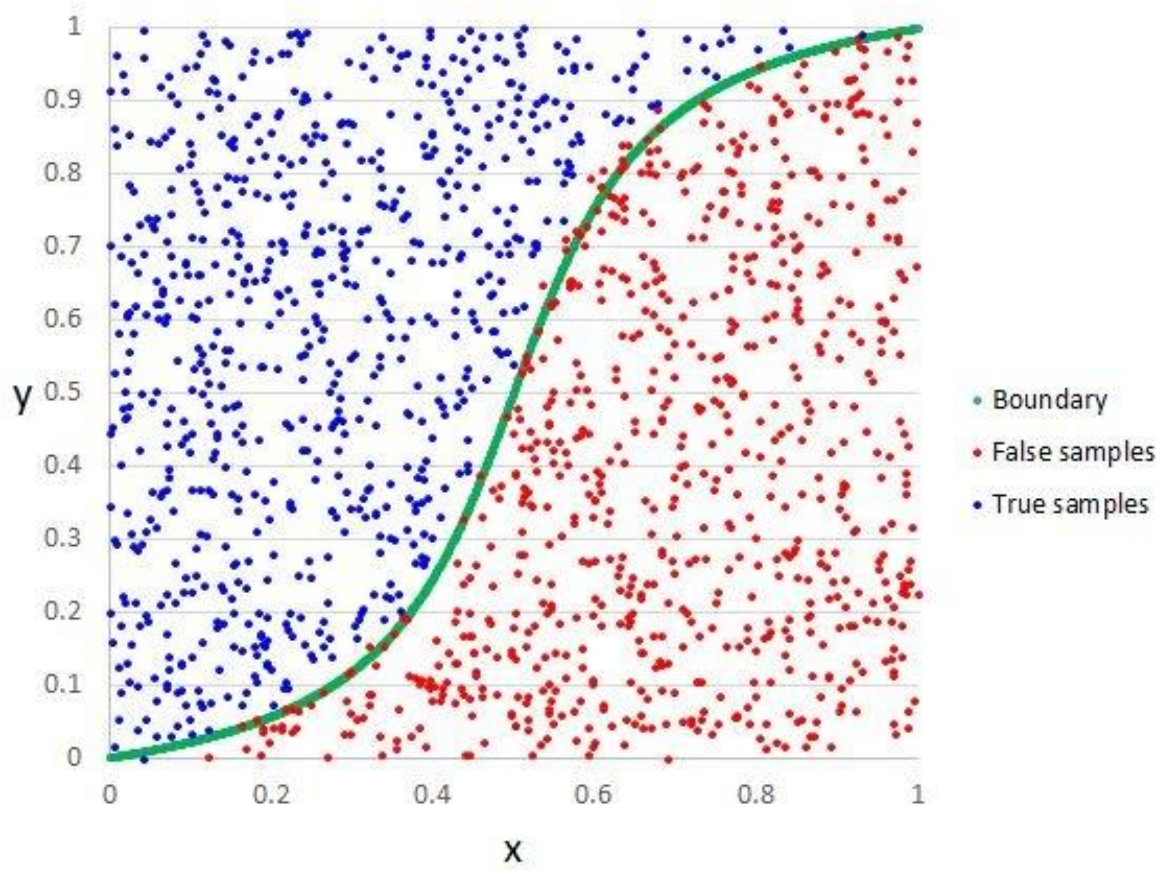
   4. Update the model:

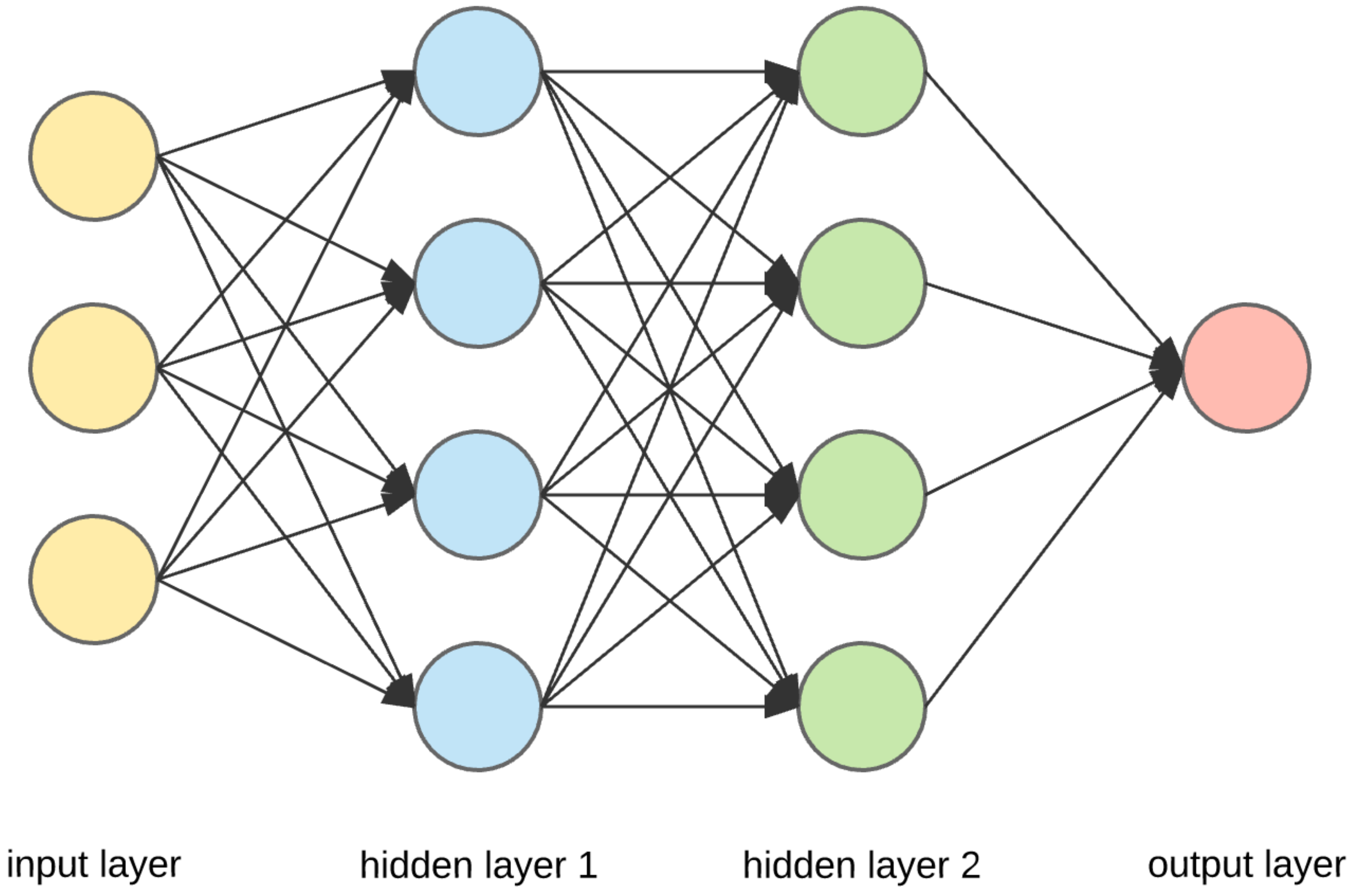
   $$F_m(x) = F_{m-1}(x) + \gamma_m h_m(x).$$

3. Output $F_M(x)$.

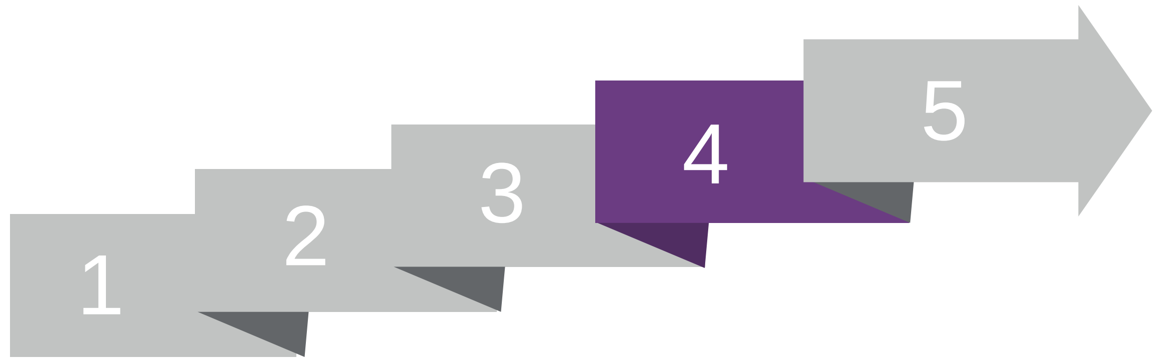








Piloting and Testing of Advanced Algorithms



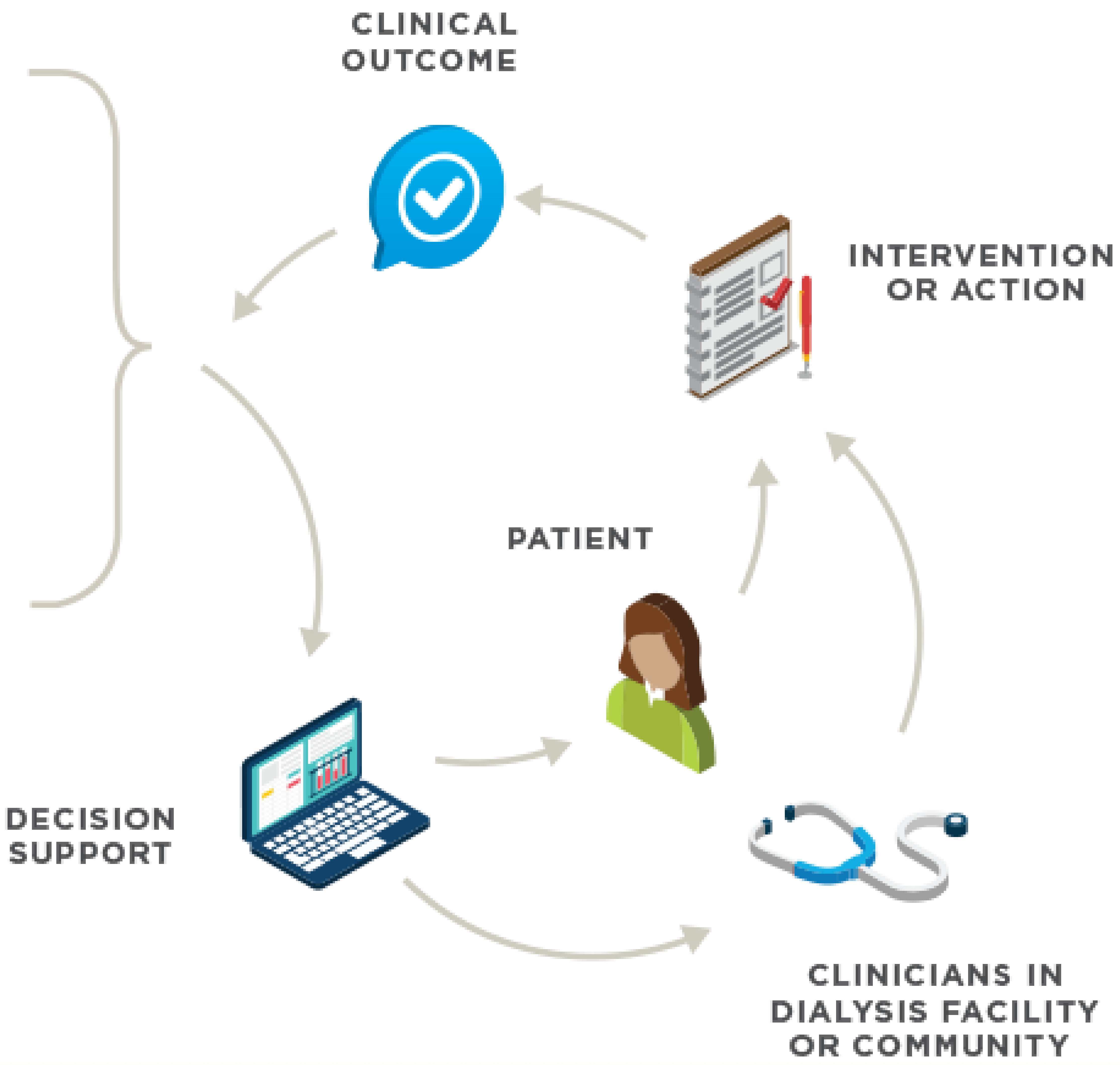
DATA SOURCES

INTERNAL DATA SOURCES (EHR)

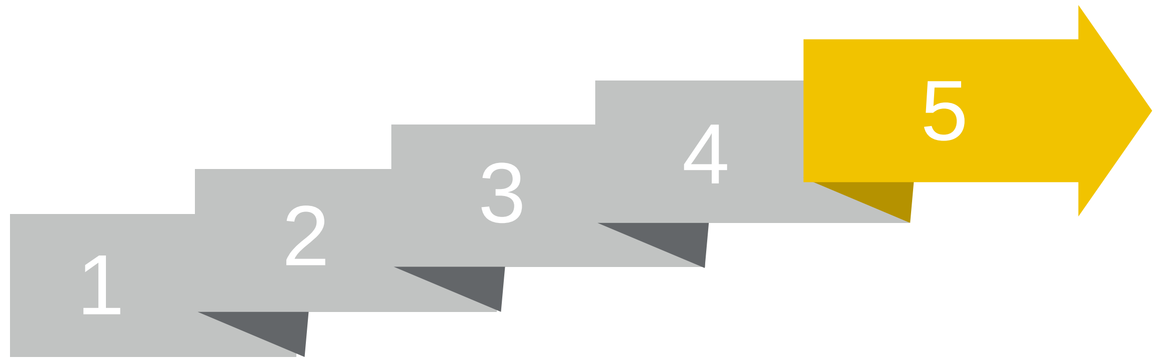
Demographics, clinical parameters, treatment history, medical history & medications, access type, hospitalization

EXTERNAL DATA SOURCES

NOAA, Census Data, Social Media (Twitter, Facebook, Instagram), NASA, Amazon, Healthdata.gov, WHO, PEW Research Center, ICPSR



Roll Out and Measure Outcomes



Broad Pervasive Data Sources

Automating Modeling Efforts

Delivering Personalized Treatment Plans Company-Wide

Portfolio of Existing Efforts

Key Areas of Applied Advanced Analytics Efforts

EVENT PREDICTION

TREATMENT AID

CONDITION DIAGNOSIS

MATHEMATICAL MODELING AND ALGORITHMS

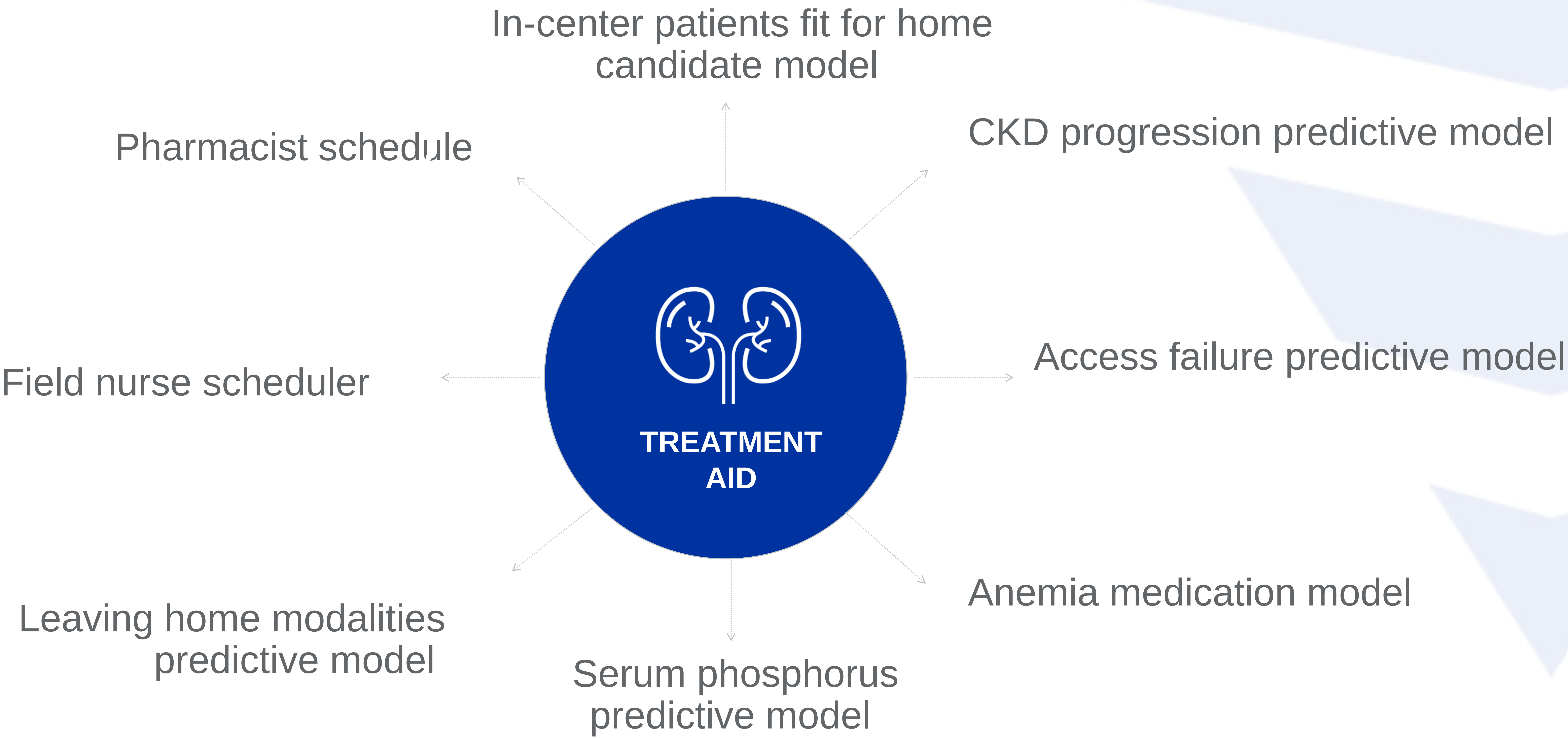
DELIVERY OF PERSONALIZED CARE AND OPTIMIZATION OF MULTIPLE PROCESSES WITHIN THE BUSINESS

Event Prediction

EVENT PREDICTION

- In-center short term hospital admission model
- Home short term hospital admission model
- In-center long term hospitalization risk model
- In-center fluid hospitalization model
- Home patients peritonitis model
- End of life prediction model
- Unexcused no show prediction model
- Blood stream infection prediction model

Treatment Aid



Condition Diagnosis

Identification of undocumented comorbidities

Clinic-level acoustic fingerprinting

CONDITION DIAGNOSIS

Foot ulcer image recognition

Access aneurism image recognition

Mathematical Modeling and Algorithms

Anemia mathematical modeling

Dietician acuity index

Bone mineral metabolism mathematical model

MATHEMATICAL MODELING AND ALGORITHMS

Social worker acuity index

Fluid status mathematical model

Functional status score

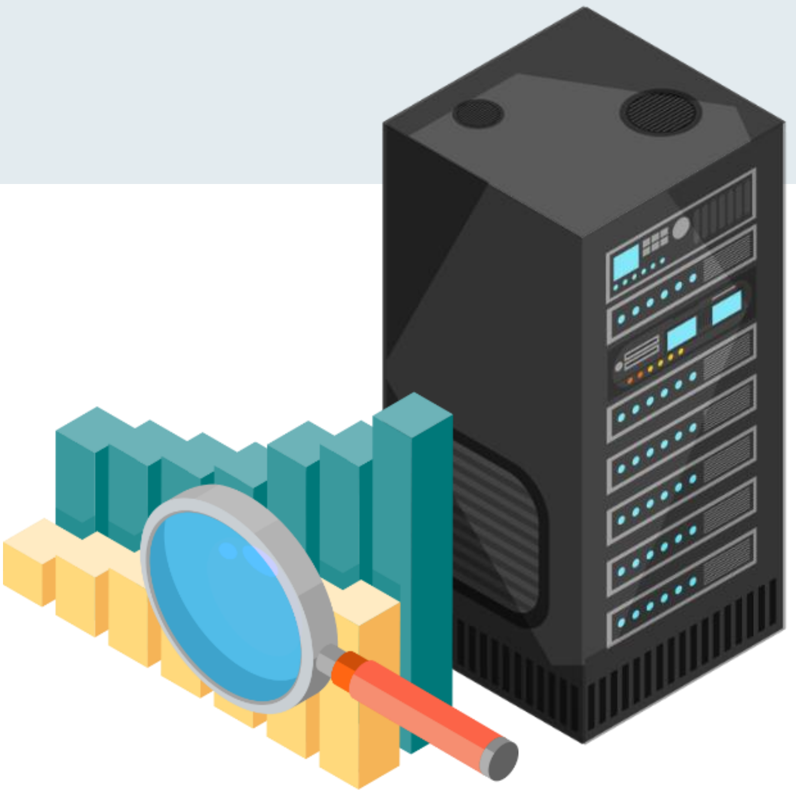
In-Center Short-Term Hospital Admission Model

Work by FMC Global Medical Office and Fresenius Health Partners

Andy Long and Adriana Lindsey

Model Definition

Predict which patients on the day of scheduled treatment are at high risk of hospital admission within 7 days



Data Extraction & Processing

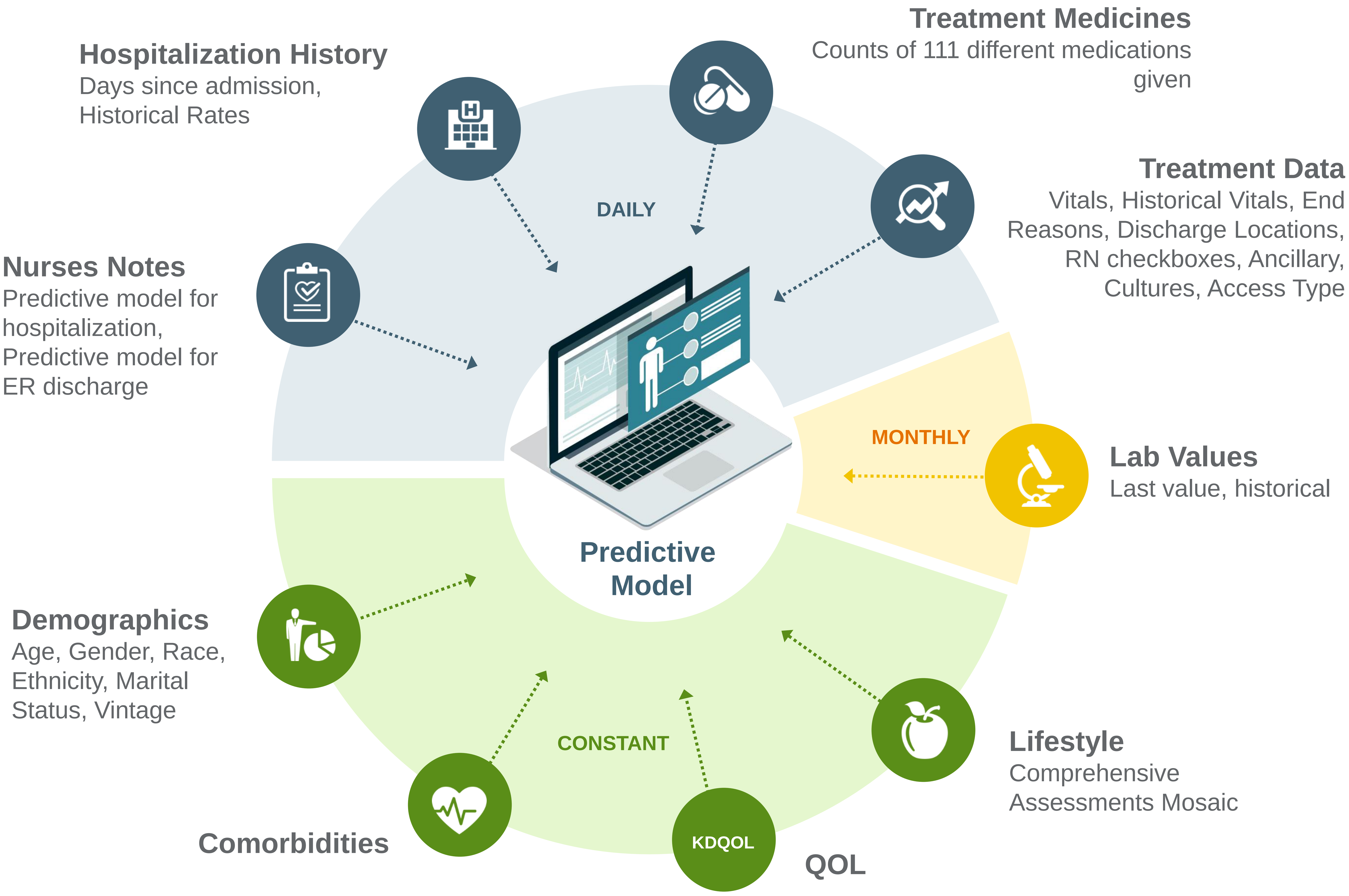
Model Building & Optimizing

Deliverables

Interventions

Data Extraction & Processing

- Data:
  Training: Jan – May 2017 (~130K hospitalizations)
- Testing: June 2017
- Number of predictors: 1,600



Data Extraction & Processing: Nursing Notes

"Patient complains of chest pain"

Nursing Notes

Abbreviations	PT C/O CP
Word Order	NO SOB, PT C/O CP" vs. "NO C/O SOB,CP"
Spelling Errors	'diarrhea','diahrrea', 'diarhea', 'dirrhea', 'diarrha', 'diarreha', 'diarrea', 'diarrrhea', 'diarrhe', 'd', 'diarhhea', 'diahrea', 'diarreah'

Built models to predict hospitalization

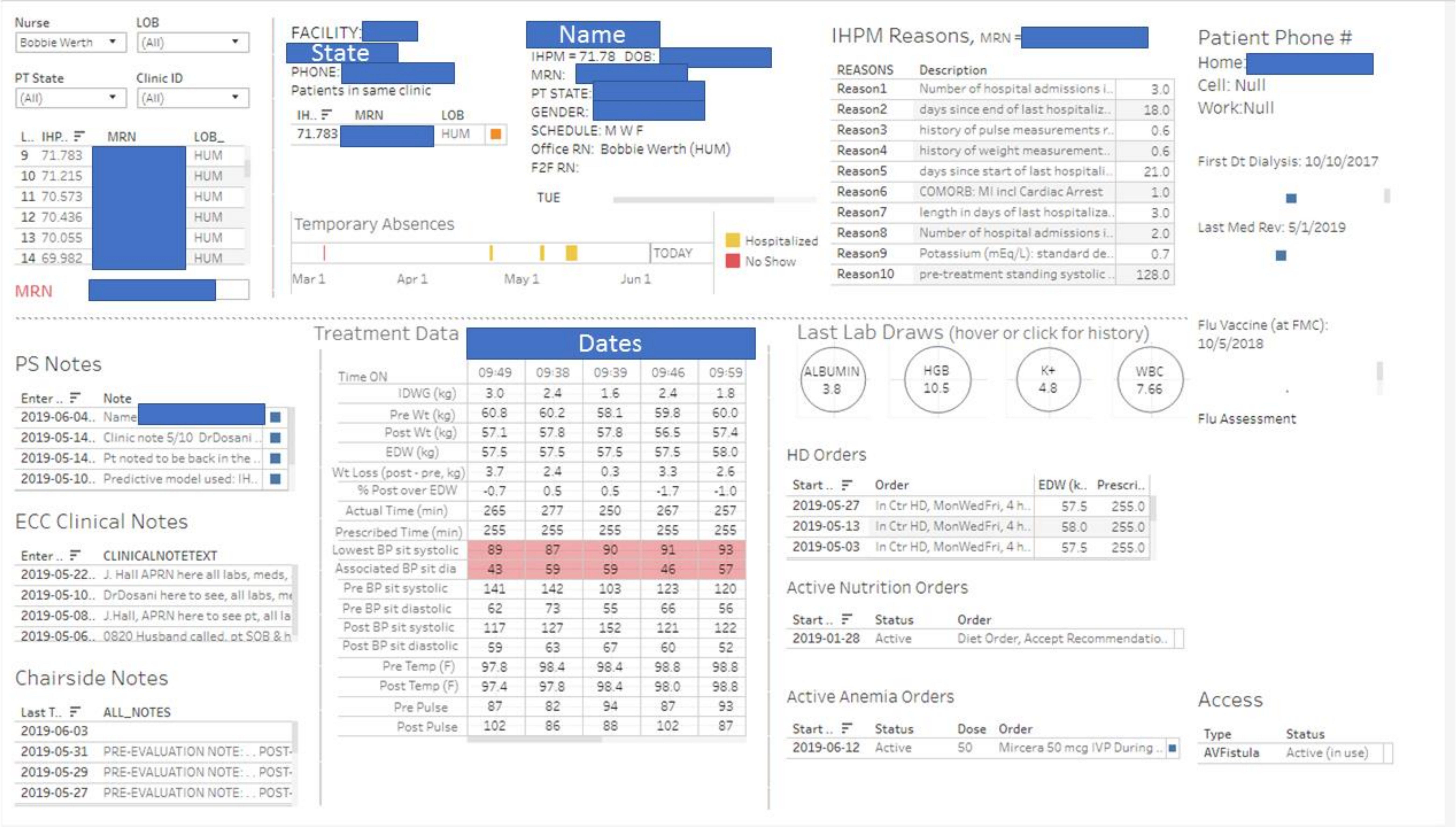
- use these probabilities as features

Model Building

- Model: XGBOOST
- Prevalence = 3%
- AUC = 0.8
- If we review 22% of patients, 21% of patients will be hospitalized

Deliverables

- Implemented February 2019 on all ESCOs/Payor Programs in FHP
- Two types of interventions:
  - Phone assessment
  - Face to face visits



Acoustic Fingerprinting

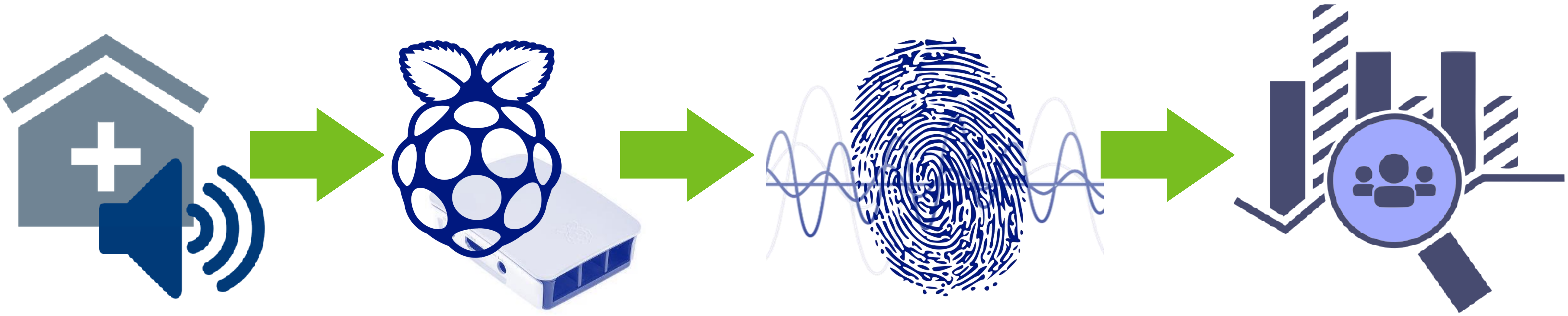
Work by FMC Global Medical Office

Caitlin Monaghan and Wendy Millette

What is Acoustic Fingerprinting?

Acoustic fingerprinting device ("acoustic sensor") allows for creation of a unique audio signature of an environment without collecting any discernable sound

How Does It Work?



Collected Data

- mean
- centroid
- spread
- skewness
- kurtosis
- decrease
- mel-frequency cepstral coefficients

  (13) . . .

	A	B	C	D	E	F	G	H	I	J	K	L
1	mean	centroid	spread	skewness	kurtosis	decrease	mfcc0	mfcc1	mfcc2	mfcc3	mfcc4	mfcc5
2	0.007759	1216.368	1717673	0.72928	2.111226	2.111226	-17.5196	1.506427	0.650881	0.455804	0.260037	0.198823
3	0.007799	1215.395	1722590	0.731666	2.112349	2.112349	-17.5072	1.518635	0.65832	0.460854	0.249059	0.195353
4	0.011475	923.999	1458066	1.246066	3.338375	3.338375	-16.0409	2.532	0.70216	0.509385	0.27007	0.106781
5	0.013044	856.7347	1349516	1.430557	3.974837	3.974837	-15.6322	2.609237	0.335869	0.623122	0.272578	0.063731
6	0.008034	1186.548	1712193	0.769397	2.164422	2.164422	-17.4041	1.518227	0.594461	0.509398	0.262881	0.210614
7	0.008062	1178.642	1711781	0.777699	2.175586	2.175586	-17.4172	1.567028	0.602185	0.476076	0.274659	0.196341
8	0.007933	1192.598	1716045	0.759679	2.148102	2.148102	-17.4375	1.548662	0.602626	0.468121	0.250198	0.176277
9	0.008043	1185.467	1713458	0.770667	2.165648	2.165648	-17.3984	1.541917	0.566621	0.454568	0.271528	0.1881
10	0.007885	1203.6	1722133	0.744534	2.127726	2.127726	-17.513	1.528027	0.646174	0.456419	0.240561	0.184783
11	0.007763	1210.253	1715395	0.738173	2.12482	2.12482	-17.5186	1.51952	0.67517	0.444031	0.238287	0.213678
12	0.007585	1254.37	1728907	0.685945	2.052459	2.052459	-17.5114	1.496119	0.638679	0.448225	0.237277	0.18106
13	0.007688	1228.25	1723621	0.716582	2.09193	2.09193	-17.5018	1.53411	0.674349	0.447073	0.222993	0.16829
14	0.007259	1290.473	1736635	0.64404	1.997306	1.997306	-17.5803	1.426311	0.509852	0.383508	0.223412	0.180037
15	0.00725	1290.004	1735445	0.644253	1.997851	1.997851	-17.5787	1.425405	0.50218	0.377021	0.206553	0.177284
16	0.007302	1289.089	1739703	0.645471	1.996885	1.996885	-17.5548	1.455731	0.509883	0.380191	0.212721	0.169758
17	0.007211	1300.903	1739812	0.63242	1.981234	1.981234	-17.5581	1.448972	0.503835	0.370136	0.208805	0.172889
18	0.007318	1284.787	1738840	0.651433	2.004595	2.004595	-17.5505	1.451786	0.51701	0.388863	0.216273	0.16872
19	0.007291	1289.026	1739298	0.646046	1.997957	1.997957	-17.5636	1.444484	0.509589	0.383973	0.214799	0.17262
20	0.007263	1288.831	1737717	0.645512	1.997355	1.997355	-17.5616	1.45879	0.516988	0.379011	0.209957	0.169144
21	0.007781	1218.012	1722135	0.728619	2.108603	2.108603	-17.5143	1.512625	0.675897	0.470822	0.257397	0.219608
22	0.007926	1200.685	1722879	0.747724	2.131195	2.131195	-17.5202	1.50892	0.638023	0.473911	0.266367	0.187448
23	0.007936	1199.161	1717570	0.750031	2.139053	2.139053	-17.5256	1.480899	0.628865	0.453105	0.25209	0.206329
24	0.00778	1220.379	1722827	0.724478	2.103035	2.103035	-17.5294	1.494082	0.6624	0.45946	0.256311	0.212779
25	0.007919	1204.29	1724058	0.743251	2.126017	2.126017	-17.5409	1.483456	0.639571	0.460003	0.248406	0.19063
26	0.007807	1217.191	1729275	0.727394	2.10023	2.10023	-17.5367	1.493128	0.630992	0.453087	0.242718	0.1897
27	0.00795	1183.767	1711248	0.768622	2.165613	2.165613	-17.5281	1.506564	0.644375	0.448177	0.241774	0.188836
28	0.007879	1207.823	1724527	0.738028	2.117956	2.117956	-17.5468	1.480478	0.625065	0.450859	0.253402	0.214074
29	0.008106	1174.565	1715280	0.779271	2.177213	2.177213	-17.5168	1.536657	0.696743	0.479608	0.268018	0.220527
30	0.007978	1190.684	1717036	0.759749	2.151189	2.151189	-17.5202	1.526726	0.664218	0.469632	0.254115	0.199673
31	0.007974	1191.514	1716384	0.758321	2.149117	2.149117	-17.5256	1.495643	0.648813	0.457052	0.256132	0.203402
32	0.007889	1204.673	1721563	0.74321	2.126609	2.126609	-17.5082	1.52388	0.661191	0.46711	0.247978	0.18745
33	0.00757	1254.887	1734588	0.683287	2.04513	2.04513	-17.5461	1.508946	0.653509	0.460737	0.238546	0.176968
34	0.007665	1238.908	1729529	0.702998	2.073038	2.073038	-17.5425	1.492553	0.664258	0.443376	0.241369	0.204717
35	0.007249	1297.153	1740591	0.636401	1.986882	1.986882	-17.5894	1.41538	0.514796	0.380107	0.209644	0.175441
36	0.007216	1302.675	1741736	0.632193	1.982274	1.982274	-17.574	1.42588	0.504687	0.380667	0.206231	0.176224

What Happens with the Data

	A	B	C	D	E	F	G	H	I	J	K	L
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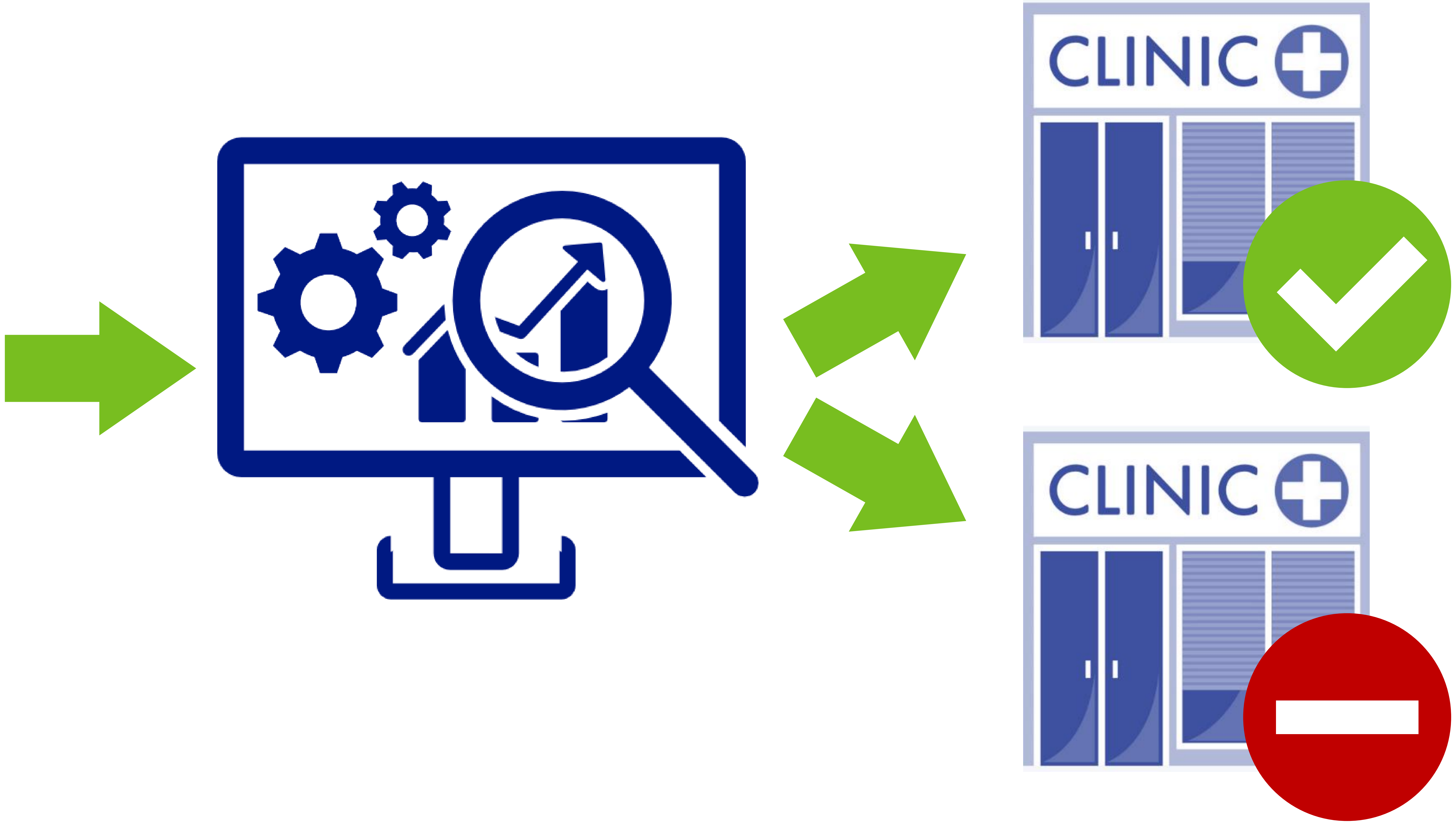
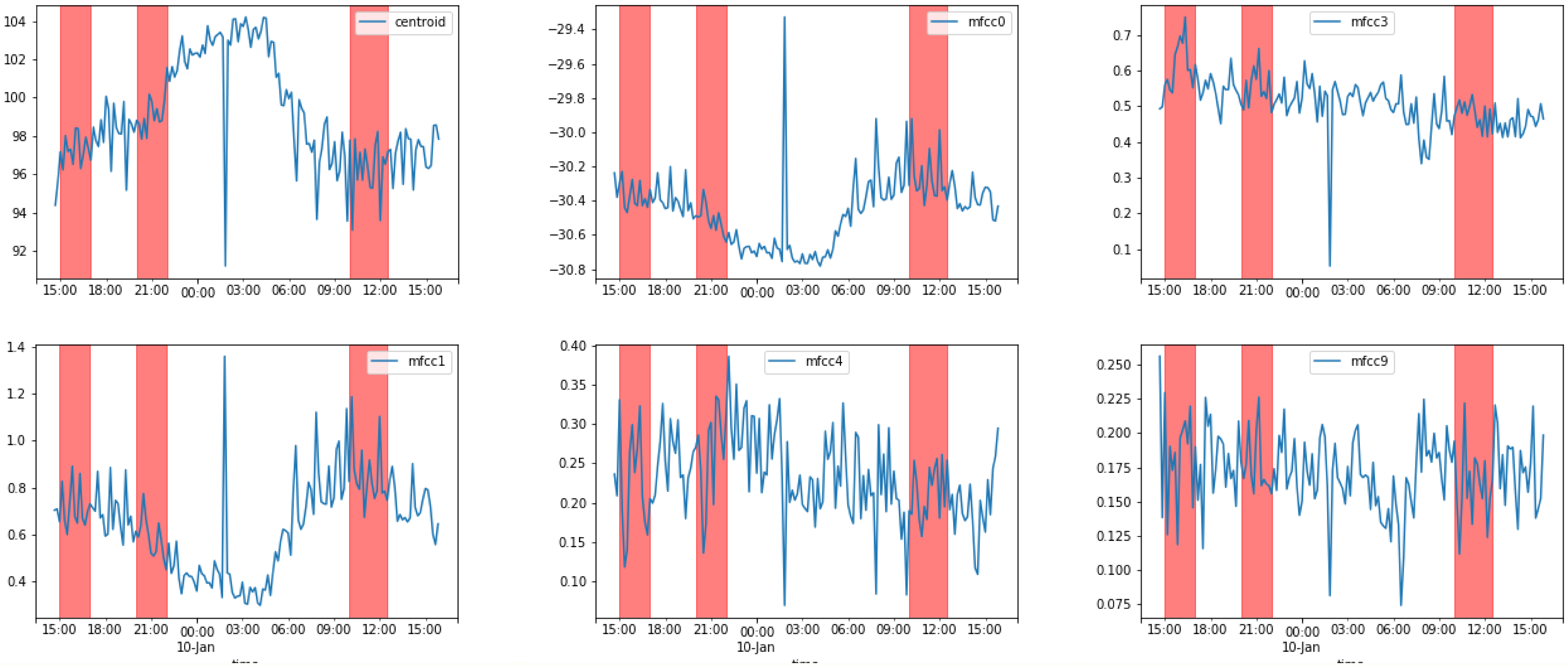
19	0.007291	1289.026	1739298	0.646046	1.997957	1.997957	-17.5636	1.444484	0.509589	0.383973	0.214799	0.17262
20	0.007263	1288.831	1737717	0.645512	1.997355	1.997355	-17.5616	1.45879	0.516988	0.379011	0.209957	0.169144
21	0.007781	1218.012	1722135	0.728619	2.108603	2.108603	-17.5143	1.512625	0.675897	0.470822	0.257397	0.219608
22	0.007926	1200.685	1722879	0.747724	2.131195	2.131195	-17.5202	1.50892	0.638023	0.473911	0.266367	0.187448
23	0.007936	1199.161	1717570	0.750031	2.139053	2.139053	-17.5256	1.480899	0.628865	0.453105	0.25209	0.206329
24	0.00778	1220.379	1722827	0.724478	2.103035	2.103035	-17.5294	1.494082	0.6624	0.45946	0.256311	0.212779
25	0.007919	1204.29	1724058	0.743251	2.126017	2.126017	-17.5409	1.483456	0.639571	0.460003	0.248406	0.19063
26	0.007807	1217.191	1729275	0.727394	2.10023	2.10023	-17.5367	1.493128	0.630992	0.453087	0.242718	0.1897
27	0.00795	1183.767	1711248	0.768622	2.165613	2.165613	-17.5281	1.506564	0.644375	0.448177	0.241774	0.188836
28	0.007879	1207.823	1724527	0.738028	2.117956	2.117956	-17.5468	1.480478	0.625065	0.450859	0.253402	0.214074
29	0.008106	1174.565	1715280	0.779271	2.177213	2.177213	-17.5168	1.536657	0.696743	0.479608	0.268018	0.220527
30	0.007978	1190.684	1717036	0.759749	2.151189	2.151189	-17.5202	1.526726	0.664218	0.469632	0.254115	0.199673
31	0.007974	1191.514	1716384	0.758321	2.149117	2.149117	-17.5256	1.495643	0.648813	0.457052	0.256132	0.203402
32	0.007889	1204.673	1721563	0.74321	2.126609	2.126609	-17.5082	1.52388	0.661191	0.46711	0.247978	0.18745
33	0.00757	1254.887	1734588	0.683287	2.04513	2.04513	-17.5461	1.508946	0.653509	0.460737	0.238546	0.176968
34	0.007665	1238.908	1729529	0.702998	2.073038	2.073038	-17.5425	1.492553	0.664258	0.443376	0.241369	0.204717
35	0.007249	1297.153	1740591	0.636401	1.986882	1.986882	-17.5894	1.41538	0.514796	0.380107	0.209644	0.175441
36	0.007216	1302.675	1741736	0.632193	1.982274	1.982274	-17.574	1.42588	0.504687	0.380667	0.206231	0.176224

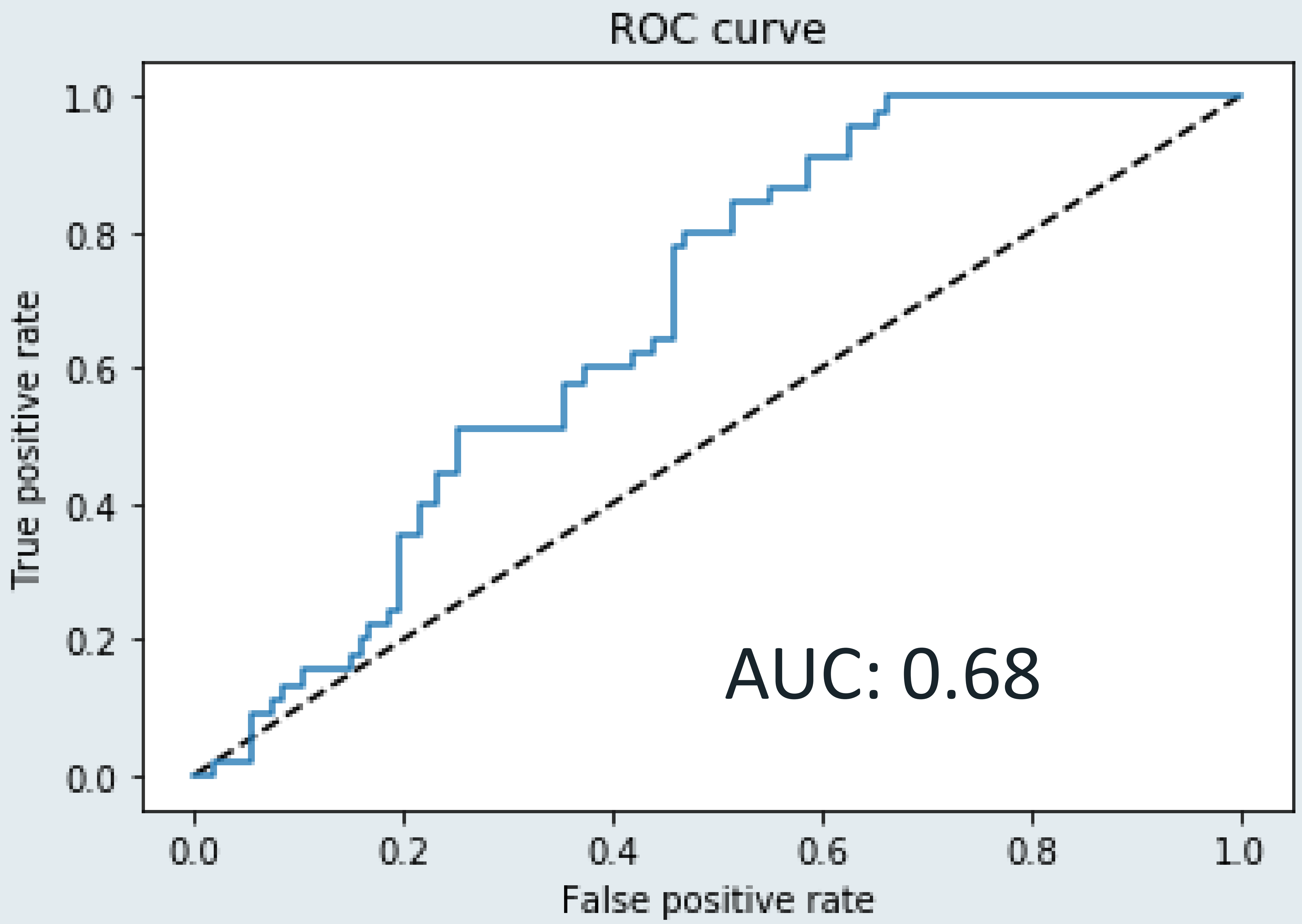


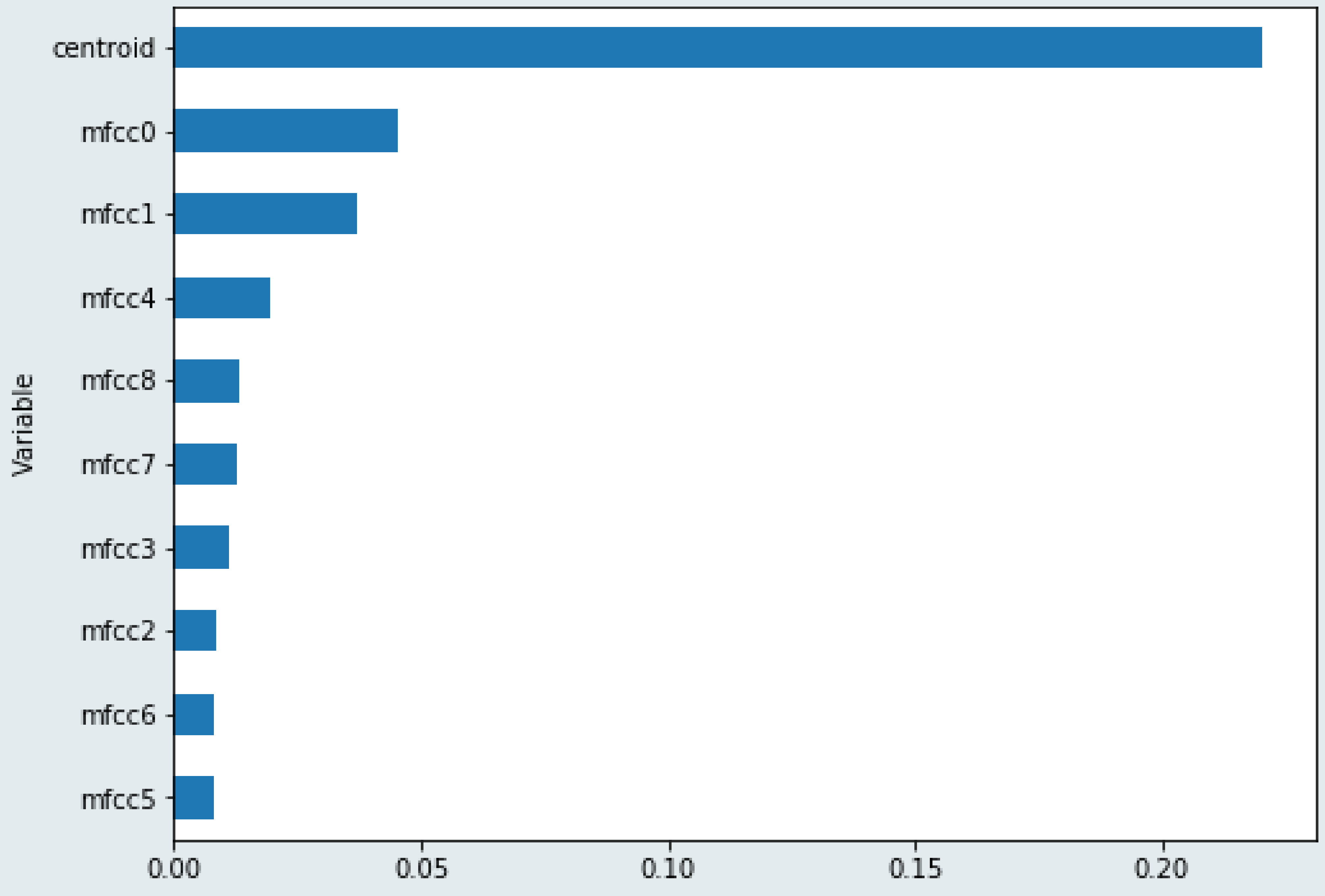
Acoustic Fingerprinting in a Dialysis Clinic



Acoustic Fingerprinting in a Dialysis Clinic

- Artificial intelligence was used to determine whether the device correctly “predicted” if patients were coming off dialysis





Current Status

- Acoustic Fingerprinting Devices are running in 4 clinics in MA since July 2019

Mathematical Modeling: Overview

Work by Renal Research Institute / FMC Global Research and Development

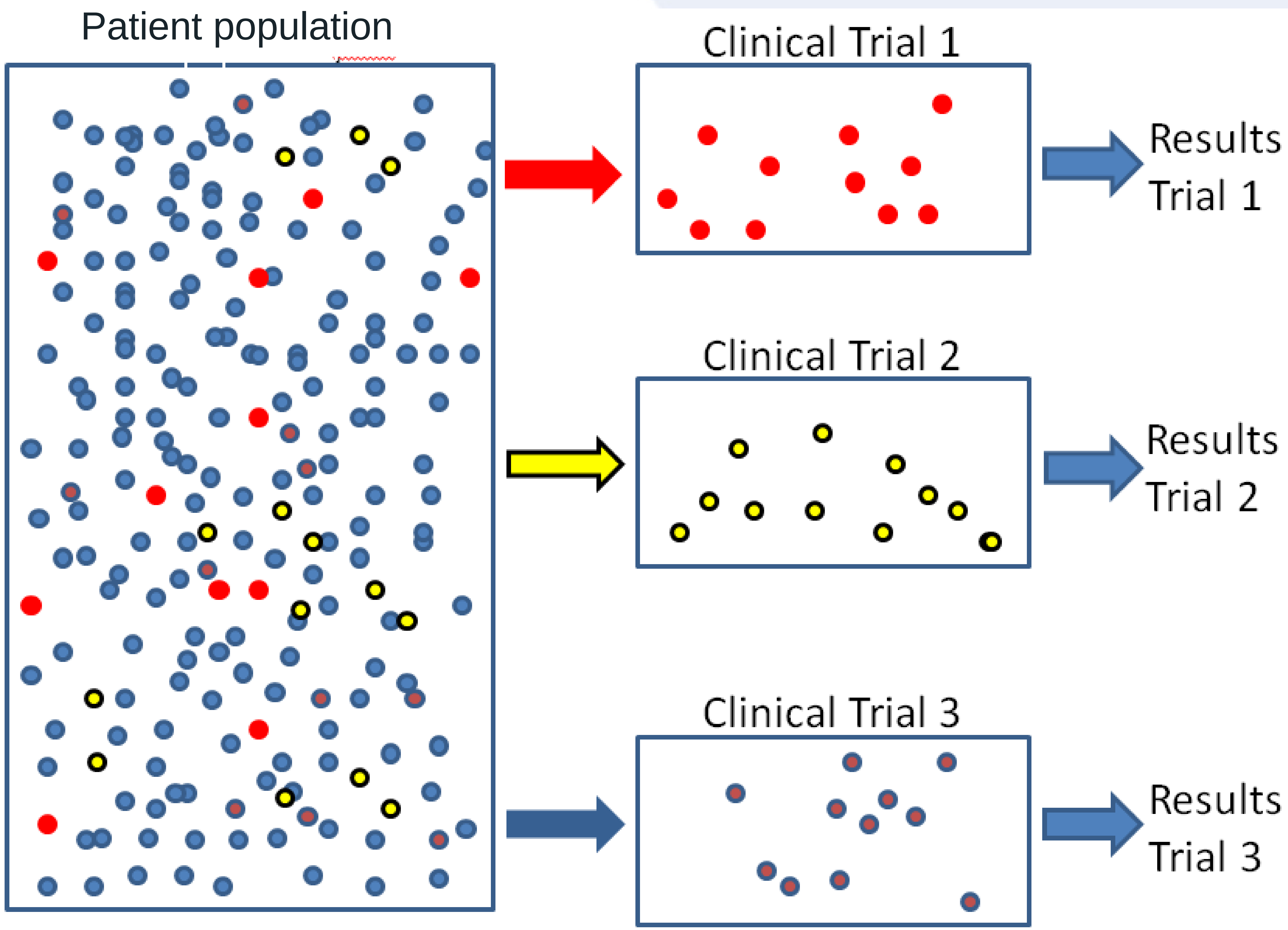
Peter Kotanko and Doris Fuertinger

21st Century Trend

- We want uniqueness in everything we do, we give and we own, right from clothes we wear to gifts we give, to coffee we drink.

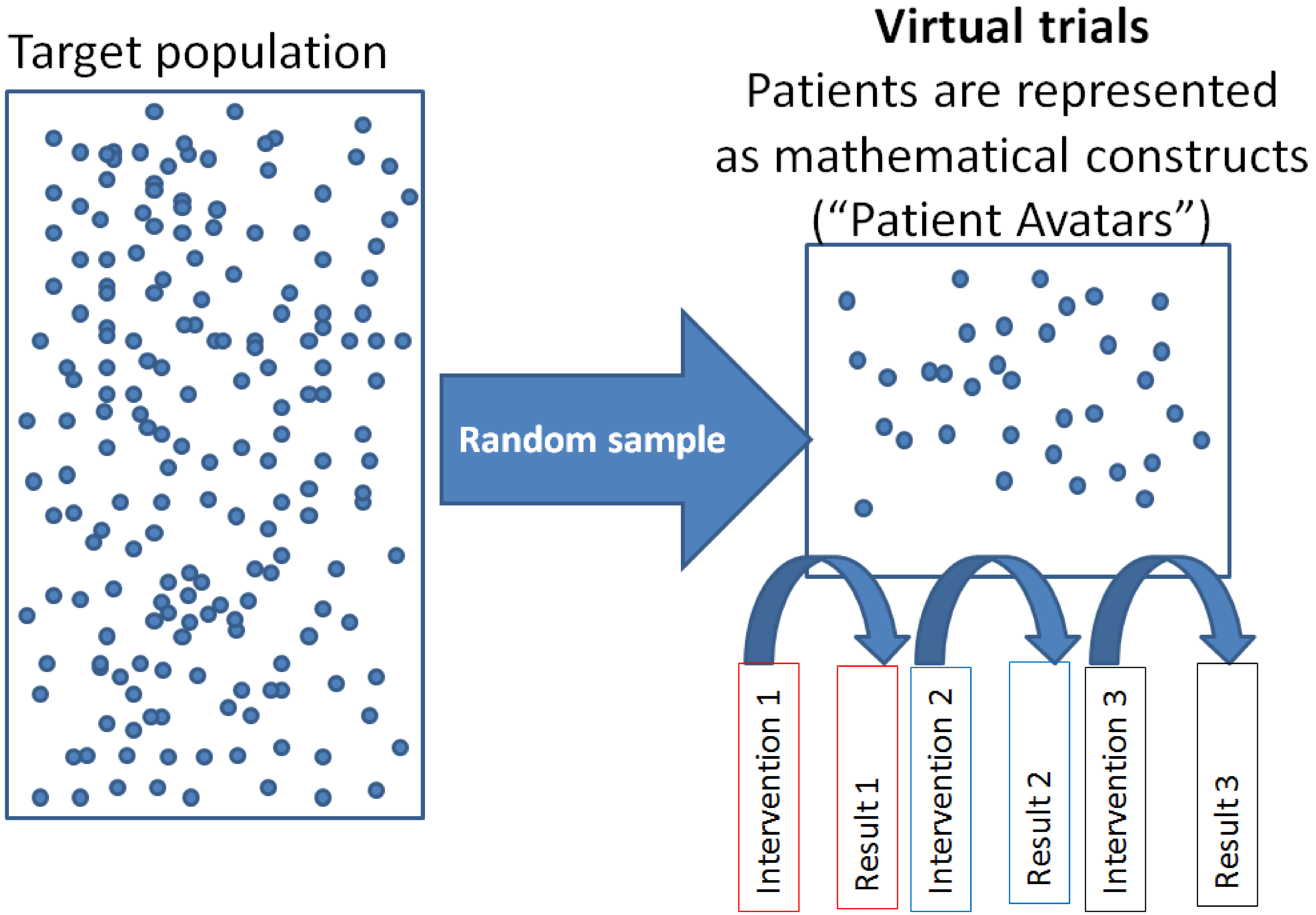
Traditional Clinical Trials

- A typical clinical trial provides only one set of results in a small & specific number of the overall patient population



Can We Create a Virtual Clinical Trial?

- Can we use mathematical principles and create „virtual“ clinical trials?
- A Virtual Clinical Trial enables testing of multiple interventions in a random large sample of patients

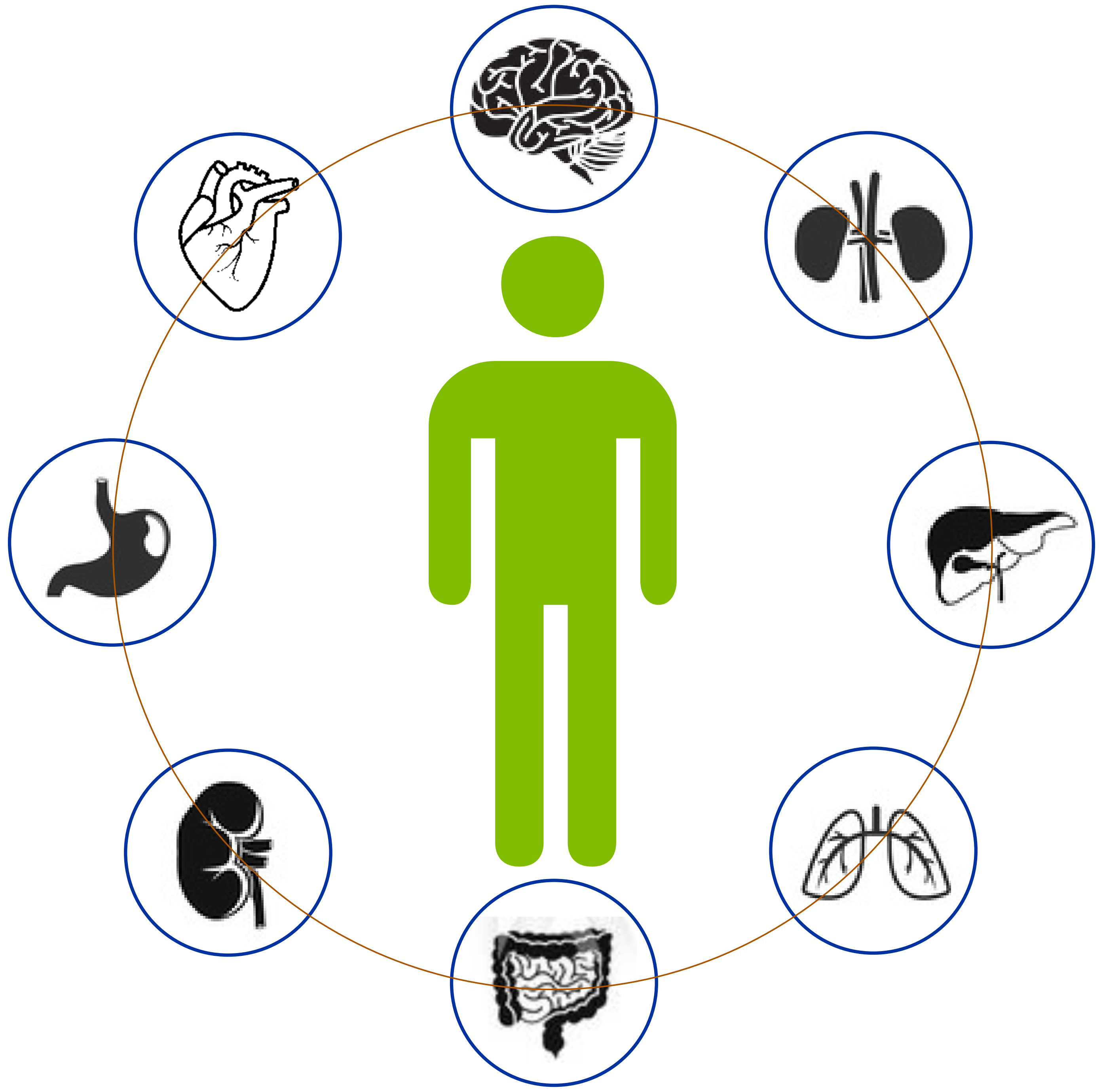


Modeling Process for Disease and Treatment

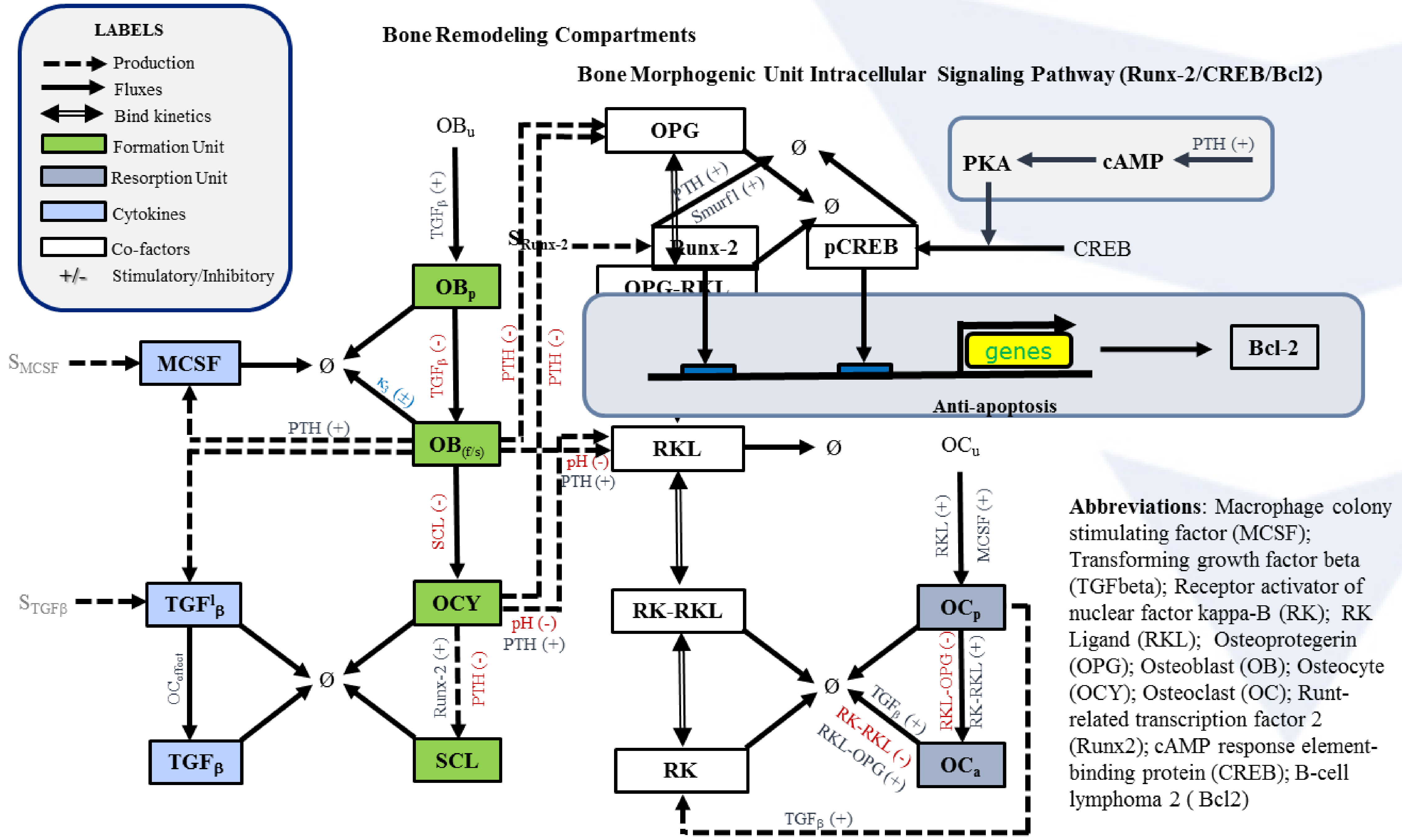
- FMC developed a "Virtual Dialysis Clinic" concept that differs from typical machine learning modeling approaches
- Process:
  - Building generic mathematical models of (patho)physiological processes
  - Creation of Avatars, representing individual patients of defined population
  - Creation of a Virtual Clinical Environment to reflect the clinical ecosystem the patient finds himself in
  - Simulation of clinical trials and drug response in individual patients

Building Mathematical Models of Physiology

General physiological processes of human bodies…

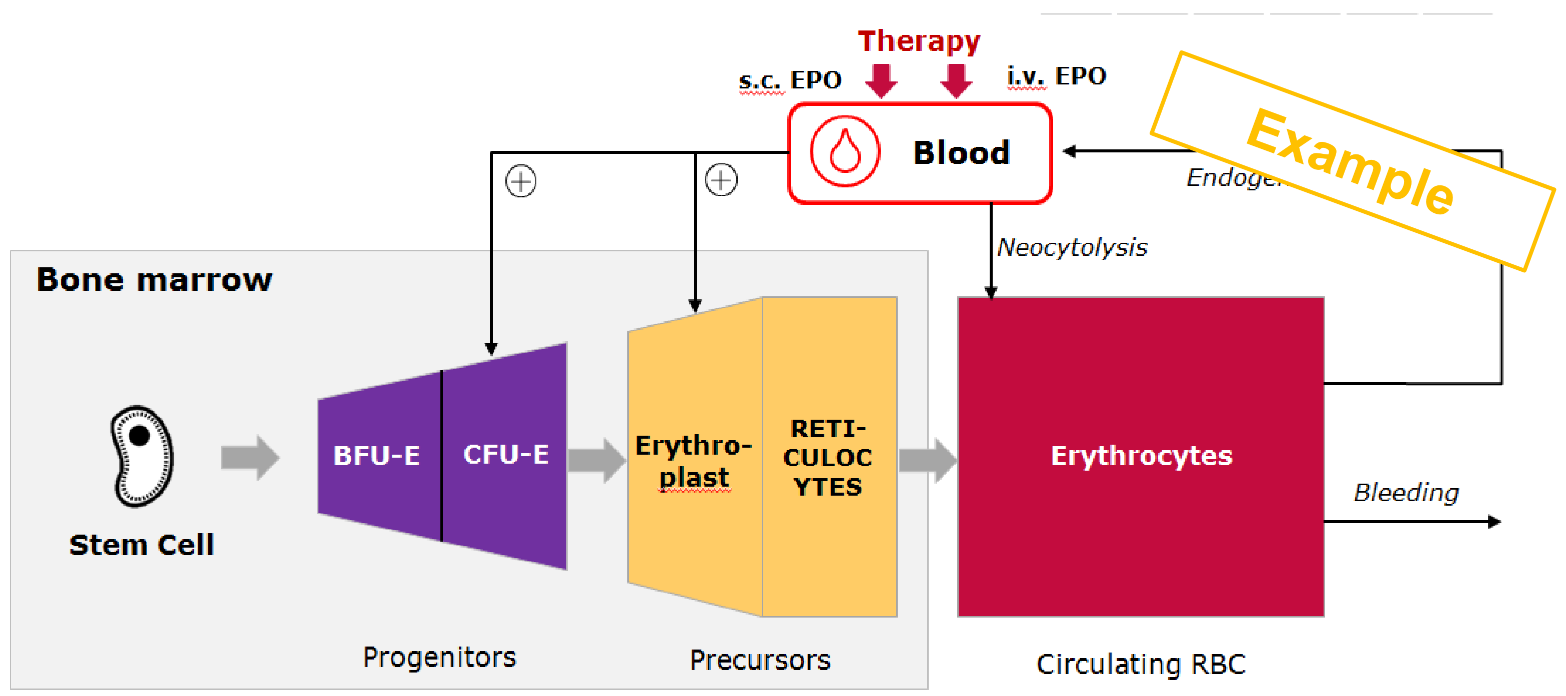


…can be represented as physiologically based mathematical models

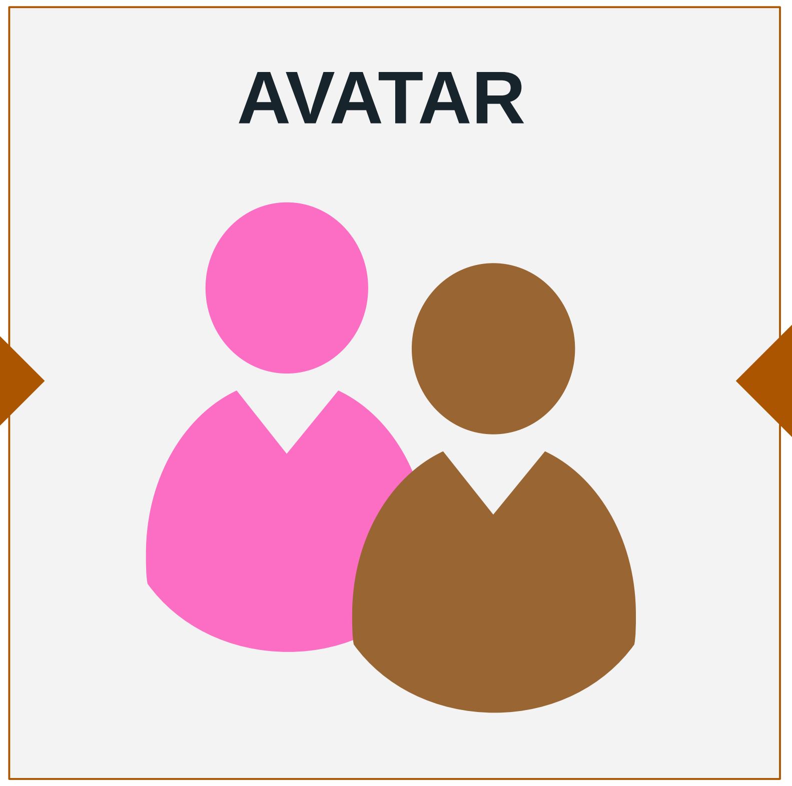


Creation of Avatars Which Represent Individual Patients

MATHEMATICAL MODEL OF PHYSIOLOGICAL PROCESSES



- Generally valid physiologically based mathematical model
- Model based on
  - Textbook knowledge
  - Expert opinion
  - Scientific literature
- Validation of model by specific test scenarios



PATIENT DATA

General Patient Data

Gender

Height

Weight

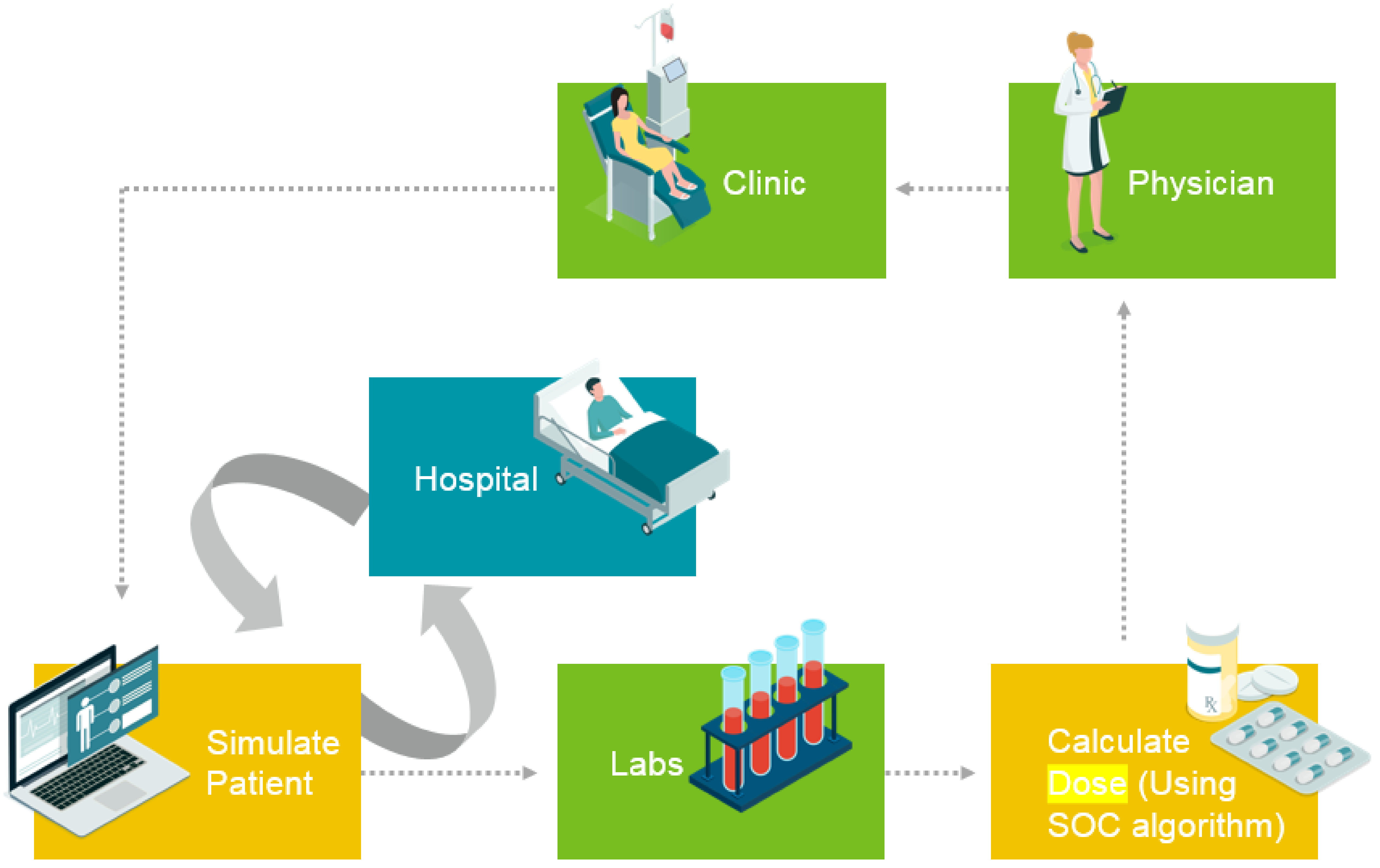
Drug admin & hemoglobin data

Selection of patient population

- Patient selection determined by clinical unmet need & defined by available data:
  - Randomly
  - Subpopulations
  - Patients with unfavorable clinical outcomes

Creation of Virtual Clinical Environment to Reflect the Clinical Ecosystem

(Example: Anemia Treatment in Dialysis patients)



- Virtual Ecosystem **integrates data from patient's daily life**.
- The Virtual Ecosystem is an important part of the **Virtual Clinic**.
- In addition to **real patient representations by Avatars**, also the **clinical environment** is incorporated in **a realistic Virtual Trial**.

Citation: CPT Pharmacometrics Syst. Pharmacol. (2018) 00, 00; doi:10.1002/psp4.12276

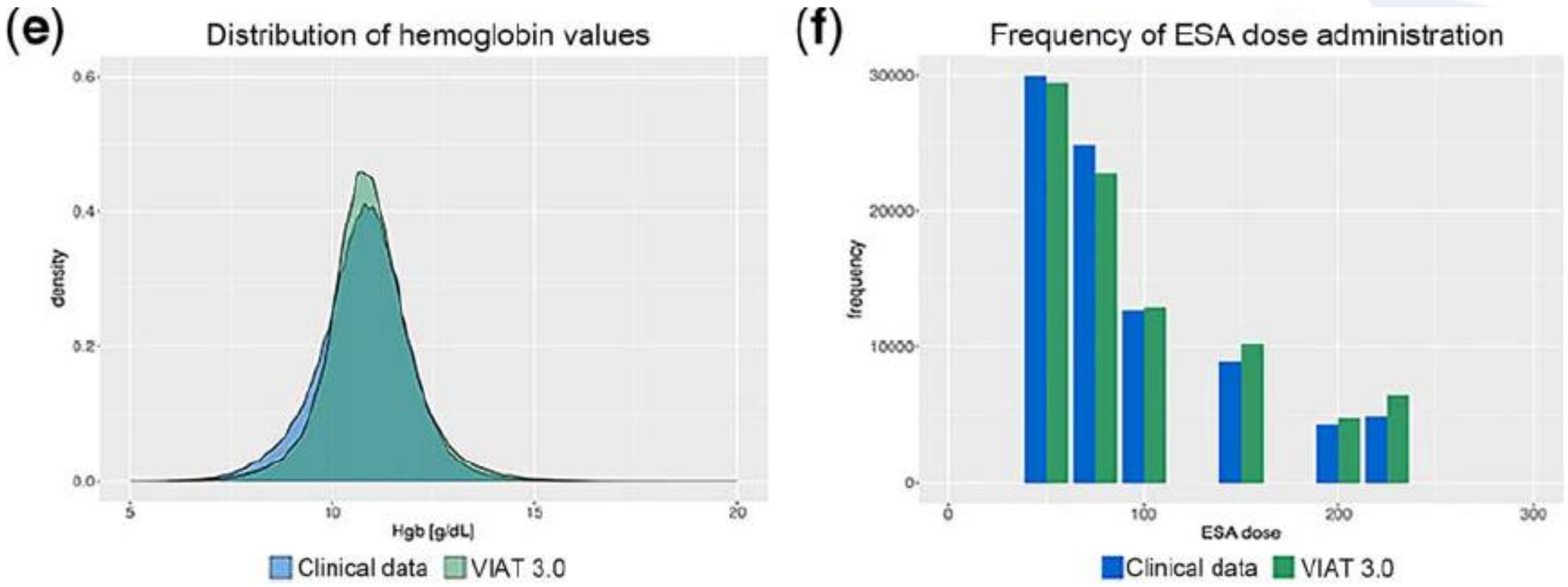
ORIGINAL ARTICLE

The Virtual Anemia Trial: An Assessment of Model-Based *In Silico* Clinical Trials of Anemia Treatment Algorithms in Patients With Hemodialysis

Doris H. Fuertinger[1,2]*, Alice Topping[1], Franz Kappel[3], Stephan Thijssen[1] and Peter Kotanko[1,4]

Simulation of Drug Response in Individual Patients

- A standard of care anemia treatment protocol was tested in ~6,700 Avatars for one virtual year and compared to one year of data from ~6,700 anemia patients treated with the same protocol



Fuertinger et al., CPT Pharmacometr. Syst. Pharmacol. (2018)

Future of AI in Healthcare

Future of AI in Healthcare

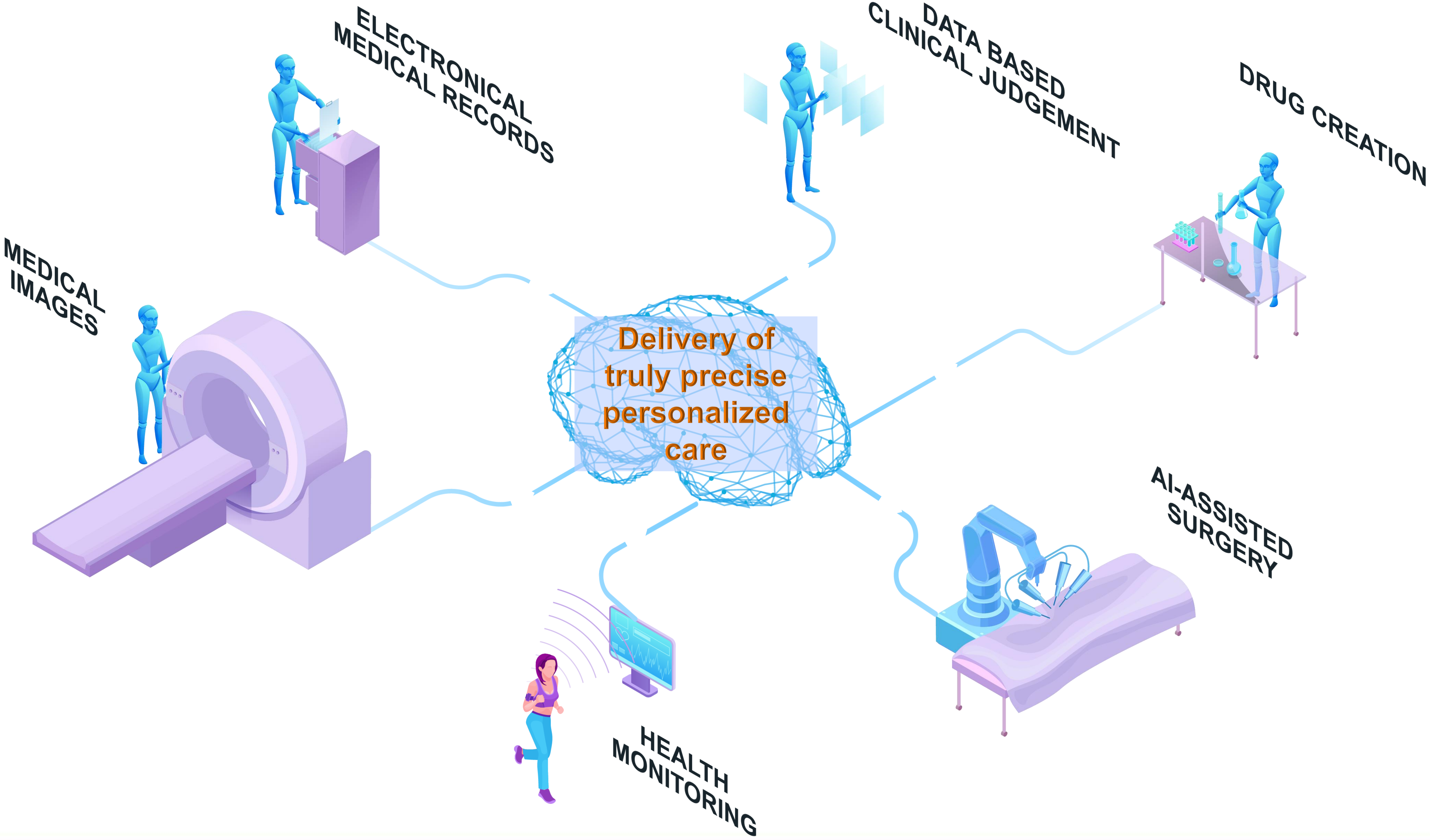
- Lots of excitement and energy
- Array of technologies are cropping up
- AI health field is wide: wellness, diagnostics, operational technologies
- Yet, AI health applications typically perform just a single task
- Regulatory framework has to catch up
- Progress will be incremental

10 AI Applications to Change Healthcare

APPLICATION	POTENTIAL ANNUAL VALUE BY 2026	KEY DRIVERS FOR ADOPTION
Robot-assisted surgery	$40B	Technological advances in robotic solutions for more types of surgery

SOURCE ACCENTURE

https://hbr.org/2018/05/10-promising-ai-applications-in-health-care


ELECTRONICAL MEDICAL RECORDS
DATA BASED CLINICAL JUDGEMENT
DRUG CREATION
MEDICAL IMAGES
Delivery of truly precise personalized care
AI-ASSISTED SURGERY
HEALTH MONITORING

Thank You!
감사합니다

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