HEADLINER USE CASE

Elevating the accuracy of diagnosis, doctor productivity and patient satisfaction with Apollo Clinical Intelligence Engine

Dr Sujoy Kar

Chief Medical Information Officer
& Vice President
Apollo Hospitals

Clinical AI – ML Programs

Snapshot of Ongoing Programs at Apollo Hospitals

September 2023

HARNESSING DILIGENTLY COLLECTED EMR DATA OVER 15 YEARS

Empowering

PATIENTS

*"enable with **better access** and meaningfully used data to promote health & wellness"*

Supporting

CLINICIANS

*"**enhancing quality of care** by comparing performance and learning from each other"*

Optimizing

OPERATIONS

*"improving **throughput**, enhancing **patient safety** and the potential for reducing healthcare cost"*

Augmenting Needs

COMMUNITY

*"creating insights & **state-of-the-art** solutions, that are user friendly and can **reach the last mile**"*

Process Flow for Planning – Design – Development - Deployment

Clinical Coordination Committee

EMR / PACS
FHIR
HL7 v2
DICOM

Data Warehouse
CSV
JSON
XML

ETL / ELT

Transformation and Harmonization

Statistical Tools & Methods
- Propensity Matching
- Descriptive Statistics
- Correlation Coefficient
- Odds / Hazard Ratio
- KM Plots & Survival Stats
- Visualization

Machine Learning Tools
- CART
- Gradient Boosting
- Natural Language Processing
- Deep Learning
- Recommendation Sys
- Reinforcement Learning
- Conv. Temporal Network
- Bayesian Structure NL

Agile Methods

API Process
Pickling
Deployment
Endpoints
Web Tech Stack
Monitoring
Security
Versioning

REQUIREMENT ANALYSIS
INPUT | OUTPUT | SOFTWARE REQUIREMENT | CLOUD REQUIREMENT

API Based Validation / Verification

Risk Management

Change & Configuration Management

Cloud Computing

bsi. ISO 13485 Medical Devices Quality Management

Internal Apollo
Apollo HOSPITALS
Apollo 24|7

Standalone Web Mobile App

Federated Learning

Digital Health Platform

Cloud Marketplace
Azure Marketplace

E A S E

https://rdcu.be/c9MN3
https://doi.org/10.1007/s40012-023-00381-2

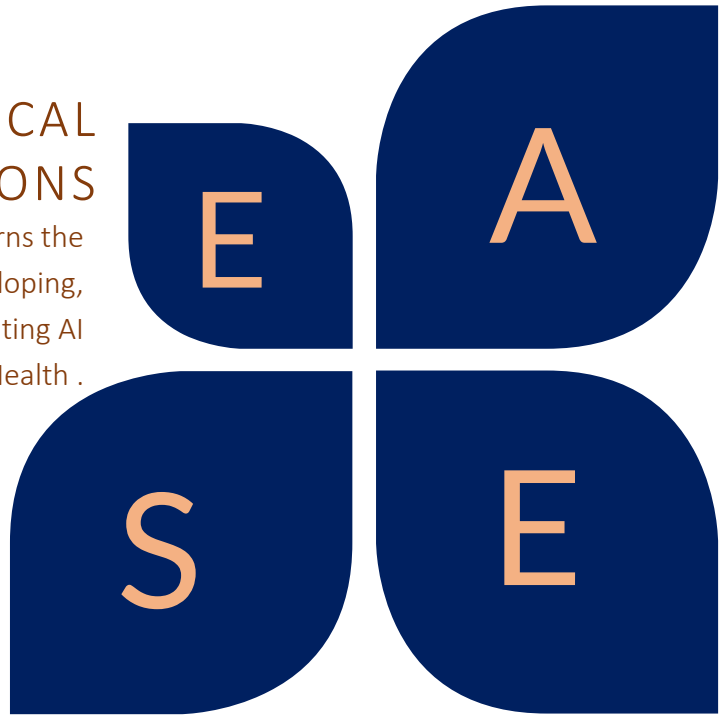
Ethics Imperative

Constituents for Ethics in AI and Digital Health

- Safety & Non-Maleficence
- Accountability
- Efficacy
- Accuracy
- Integrity
- Fairness & Inclusivity

ETHICAL CONSIDERATIONS

The principles that governs the ethical aspects of developing, validating and implementing AI and Digital Health .



ADOPTION

How are Clinical AI and Digital Health Programs implemented – the change management of things

- Interoperability
- Universalization
- Calibration - Benchmarking
- Clinical Relevant Outcomes
- Patient Safety

- Clinical Need
- Addressing Bias
- Practical Accuracy
- Human-Machine Handoffs

SUITABILITY

The aspects that deal with what is suitable for a Clinical AI Program – What Works and What Does not ...

https://rdcu.be/c9MN3
https://doi.org/10.1007/s40012-023-00381-2

EXPLAINABILITY

How we make the Clinical AI Models and components of Digital Health much easier for understanding and implementation

- Verifying before Deciding
- Building Trust in System
- Counterfactual Reasoning
- New Clinical Insights

EASE Framework is an Apollo Hospitals Concept

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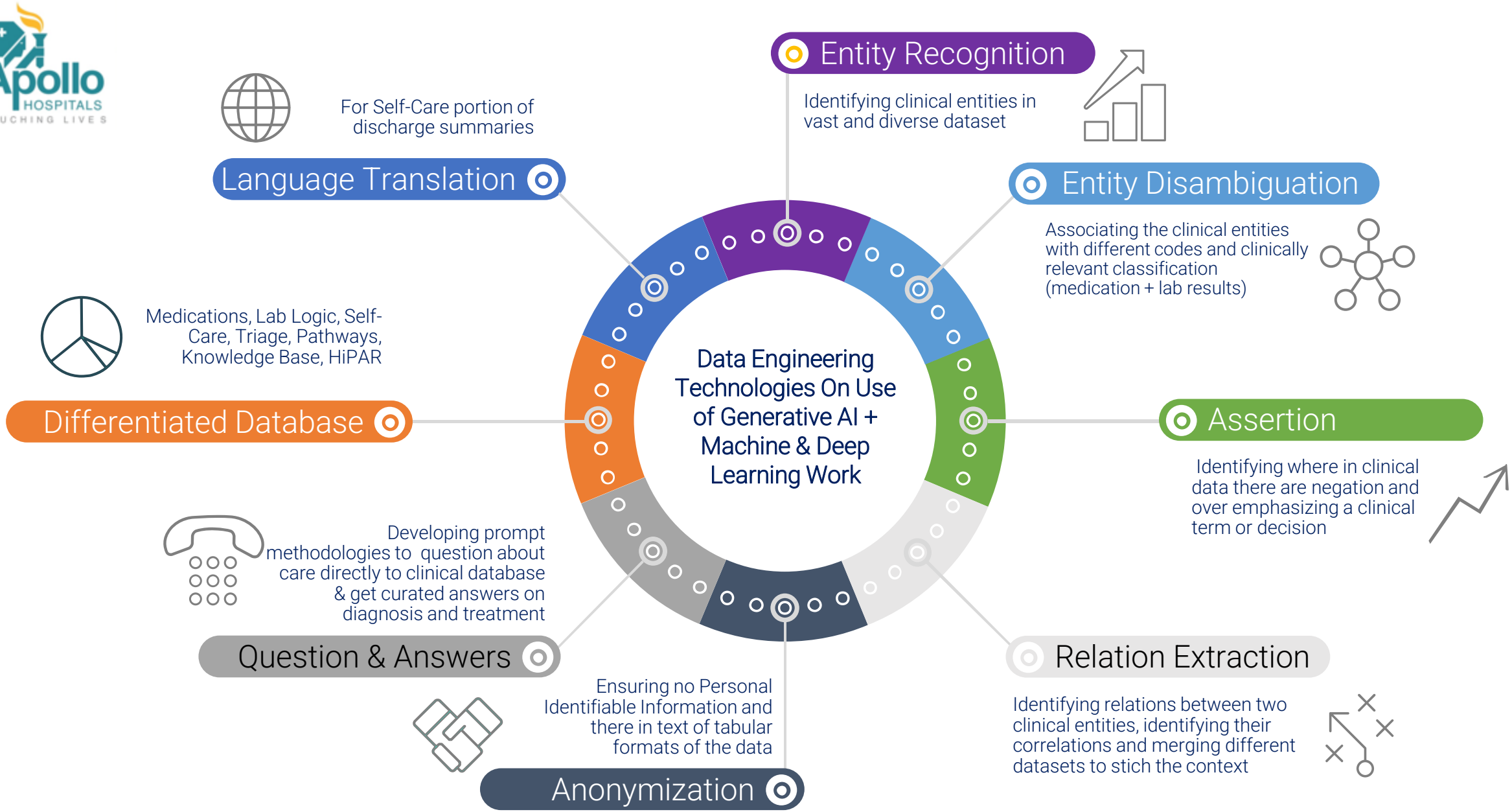
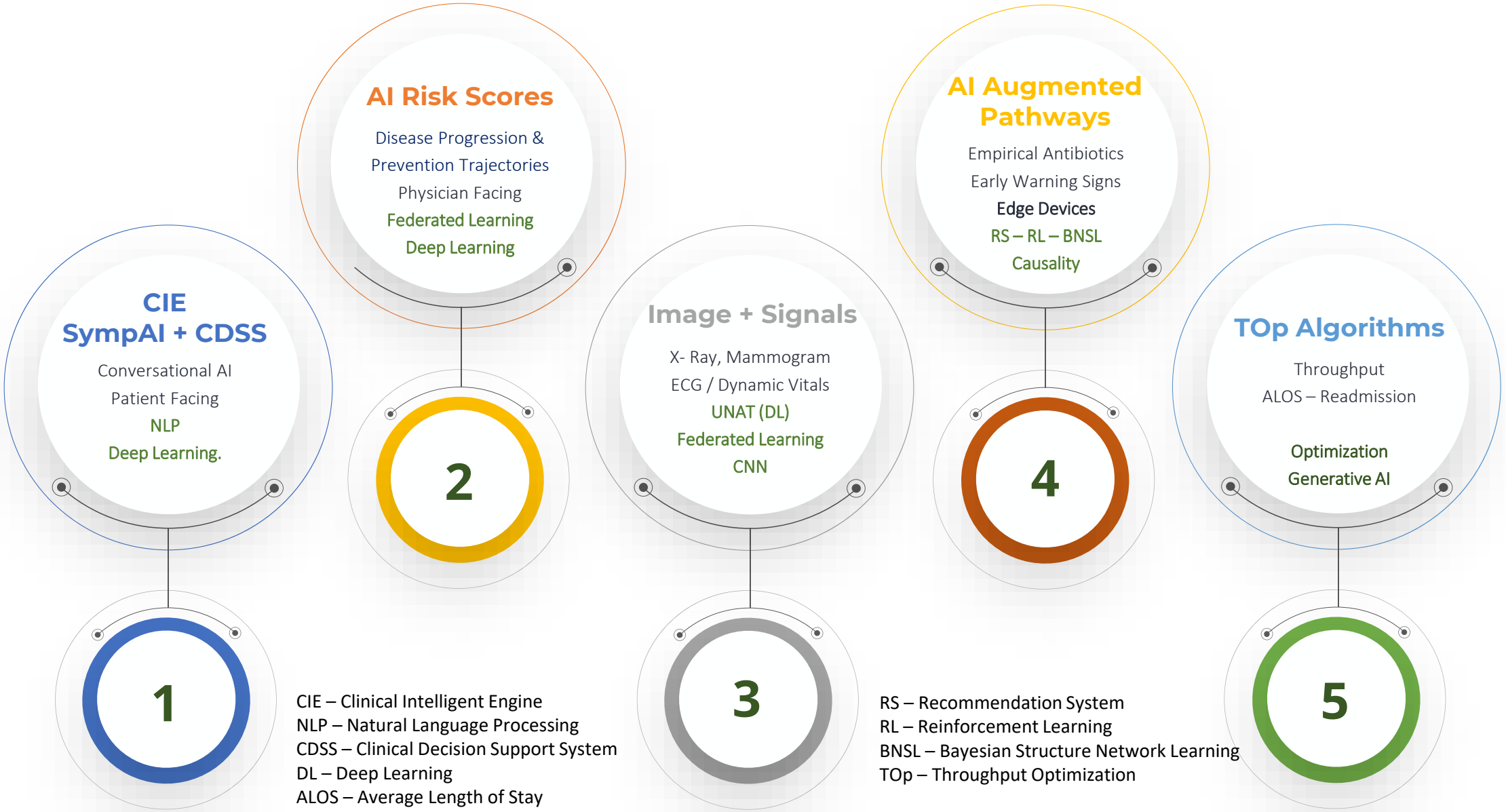


Clinical AI Workstreams



CIE – Clinical Intelligent Engine
NLP – Natural Language Processing
CDSS – Clinical Decision Support System
DL – Deep Learning
ALOS – Average Length of Stay

RS – Recommendation System
RL – Reinforcement Learning
BNSL – Bayesian Structure Network Learning
TOp – Throughput Optimization

Bring **Apollo Clinical Expertise** to every user interaction

Apollo 24|7 CIE

For Customers/Patients

Contextual Health Info discovery & Next best action

Discover causes to symptoms

10% of users in 247 typically search via symptoms, diagnosis, etc. **50MM+** people search on google

Discover Labs/Imaging

50%+ users do not know what tests to do

Drug Interactions - Safety Advice

Typically, **2%+** prescriptions have drug interactions

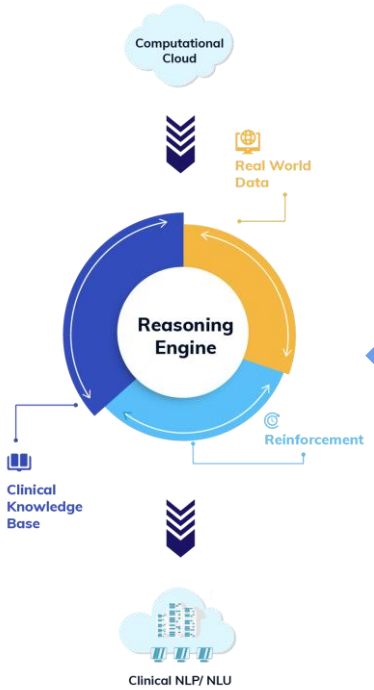
Discover Specialty and Doctors

25%+ people do not know which doctor to see

Health Genie

Constantly watch a consumer's record to find issues in medications, provide actionable next steps, etc

Data Science & Machine Learning



Medical Intelligence Platform

For Clinicians

AI assistance in clinical practice

CIE assisted Doctor consult

Collect complete history by asking right questions, assist doctor in rare diagnosis

Case Info

Automated process that mimics a typical doctor-patient interaction to triage serious cases and collect symptoms and past history info of the case at hand

Case Summarisation

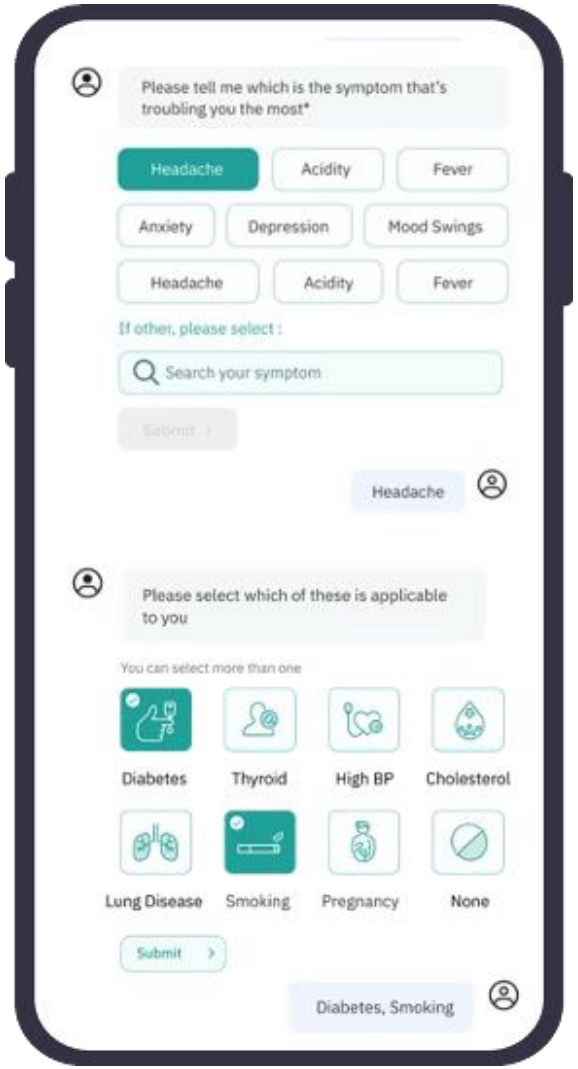
Automated case summary is generated, including real time extraction of past history from previous encounters. Saves times in OP, helps focus on diagnosis and treatment

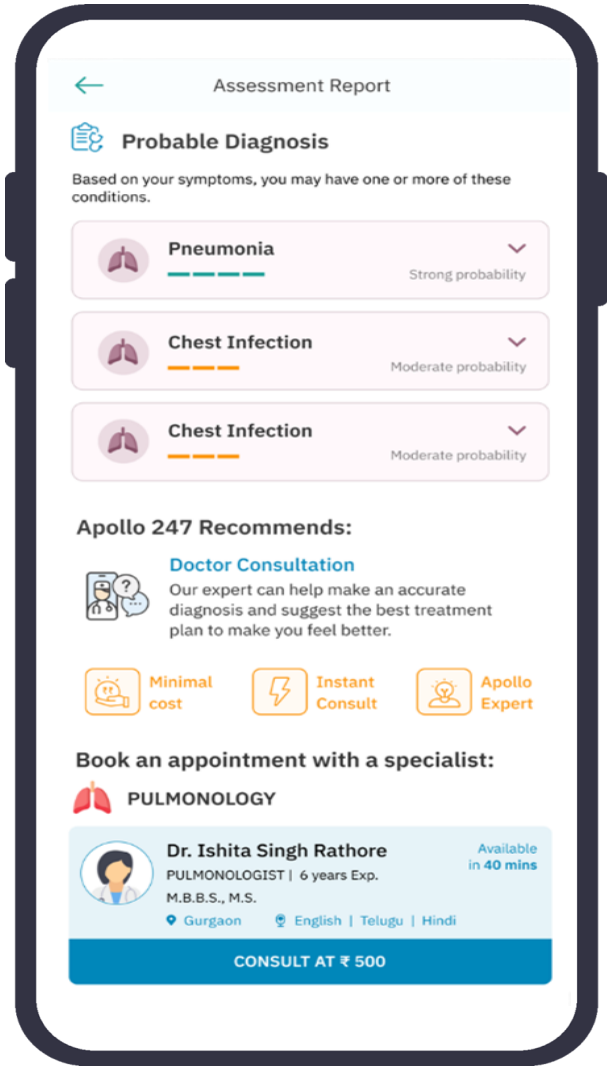
Case Analysis

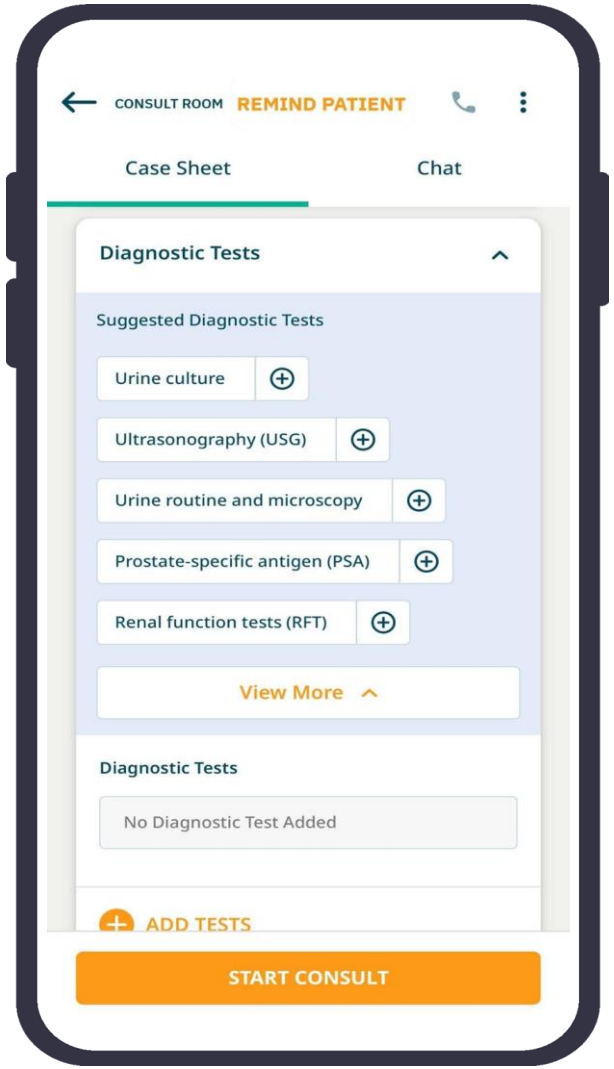
Clinical recommendations are built using Apollo's vast clinical data repository. Next best steps are suggested with explainability to help doctors consider all possibilities before finalising diagnosis and treatment

Clinical Intelligence Engine

SympAI & CDSS







Key Highlight

10-15%
Clinician time saved

Used by **1500+** doctors across specialties

Covers **1300** conditions and **800** symptoms

Covers **95%** of Daily case mix in outpatient setting

>80% Accuracy with Google partnership (Benchmark 50-60%)

For Customers / Patients [247 Platform] –
Contextual Health Info discovery & Next best action

For Clinicians
AI assistance in clinical practice

AI based Disease Progression & Risk Score Models

- Design – Development – Deployment

Problem we faced

Growing epidemic of non-communicable diseases like Cardiovascular Diseases, Diabetes, Kidney Failure, Liver Fibrosis etc.

Risk scores for NCDs onset to help identify at-risk patients

Value Creation: Methodology

Longitudinal Patient Data 5 – 10 years

Over 100+ clinical predictors from health check and discharge data

Deep Learning Algorithms with Time to Event Hazard Analysis – Accuracy [0.86 – 0.92]

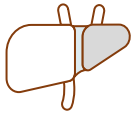
Based on risk category recommends peer reviewed Clinical Pathways [Next best action]

ISO – 13485 Certification [SaMD]

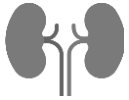
Value Capture: Deployment

AICVD

Pre-Diabetes AI



AI-LF



AICKD

AICOPD

AICVA

Validation

In different geographic, ethnic and socio-economic population worldwide

Prospective Use Feedback loop

Integrated to EMR & digital health platforms data from the users help calibration of the model across ecosystems

Personalized

Provides personalized recommendations to reduce the modifiable risks through holistic program

Key Highlight

API Calls (Since Jan 2022)

870K+ Apollo Hospitals

10K+ Outside Apollo Hospitals (July 2023)

Inferences

AICVD Stats

High Risk	14%
Moderate Risk	17%

Prediabetes AI

High Risk	0.6%
Moderate Risk	9.3%

AI based Disease Progression & Risk Score Models

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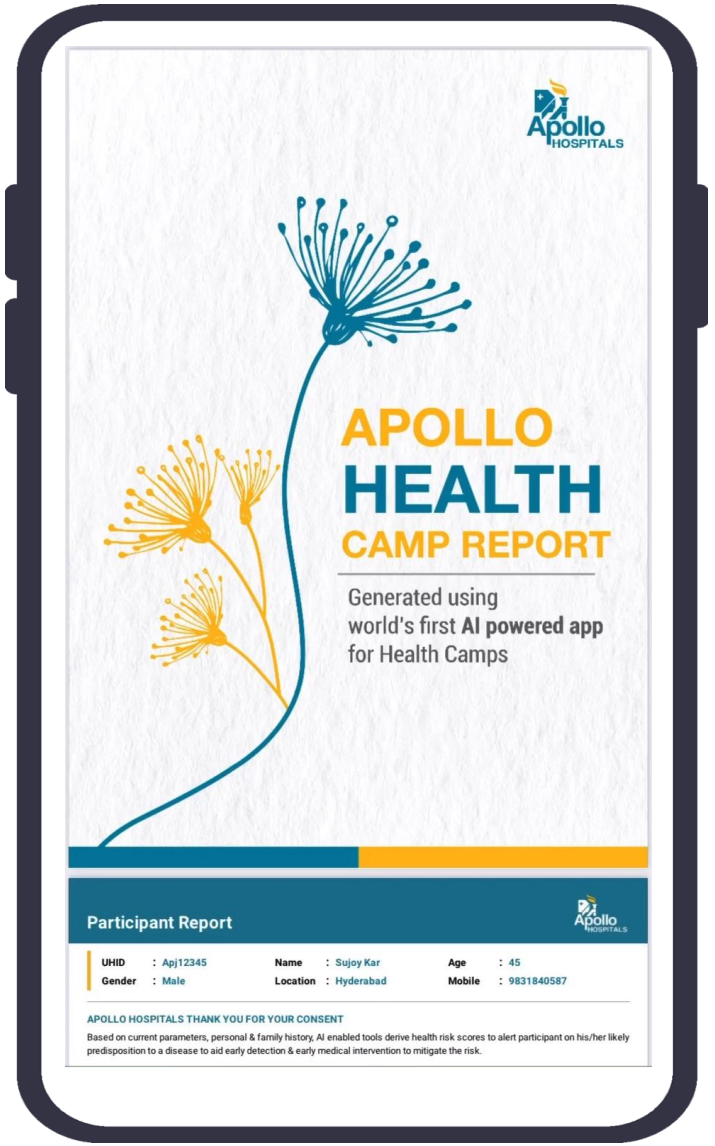


AI Based Risk Scores – Integration to Fitbit <> ConnectedLife

Patient is identified for population health assessment

Patient

1

Books appointment and fills up **pre-assessment survey**

2

Visits the Doctor/Pharmacist, completes assessment survey

3

Patient is onboarded onto **ConnectedLife with Fitbit**

4

AICVD questionnaire is completed and prepopulated with onboarding data from wearable and onboarding data

5

AICVD reported generated including recommendations to improve.

6

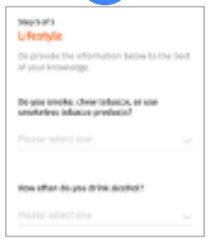
Nudges and reminders based on recommendations in the report

Patient continues to be monitored for improvement in CVD risk

7

Solution prompts users to log their **lifestyle parameters**

8



Solution prompts users to log their **smoking & drinking Habits**

9

AICVD risk assessment tool helps to understand monthly reassessment of scores which highlight how the score changes with lifestyle parameters. Indicating if a user is on track to improve their risk

10

View longitudinal changes in the CVD risk score over time. Patient gets a reminder every 6 months for an in person appointment

11

In-person visit – Reminder every 6 months for in person visit.

12

Patient enters Healthcare treatment ecosystem for more intensive assessment and monitoring of CVD symptoms

Conversion of DICOM ECG Images to Tabular Format for building Large Language Model in Diagnoses and Disease Progression of Cardiovascular Conditions

Bharath Potla, Dr Shivkumar J, Dr Sai Praveen Haranath, Dr Sujoy Kar, Dr Sangita Reddy

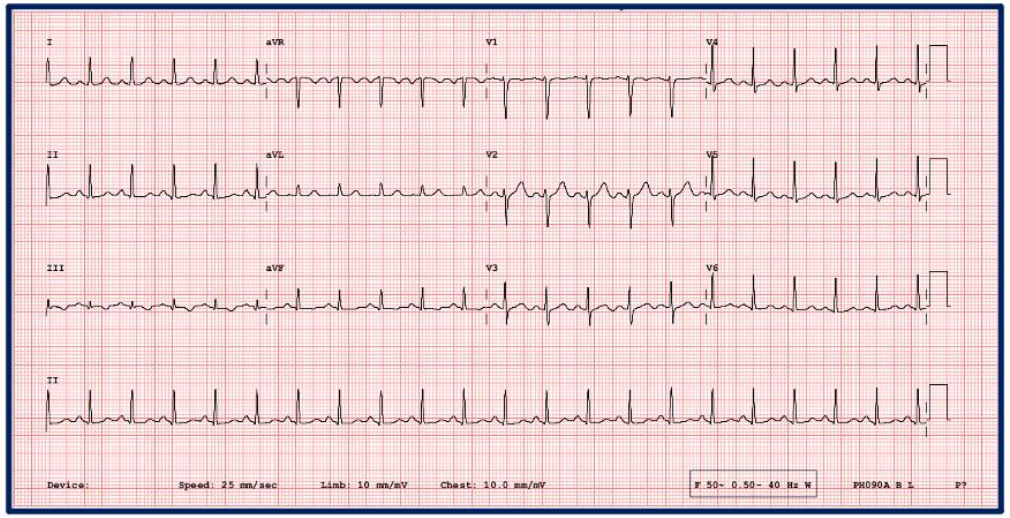


Figure 1: Sample of an Original DICOM Image ECG

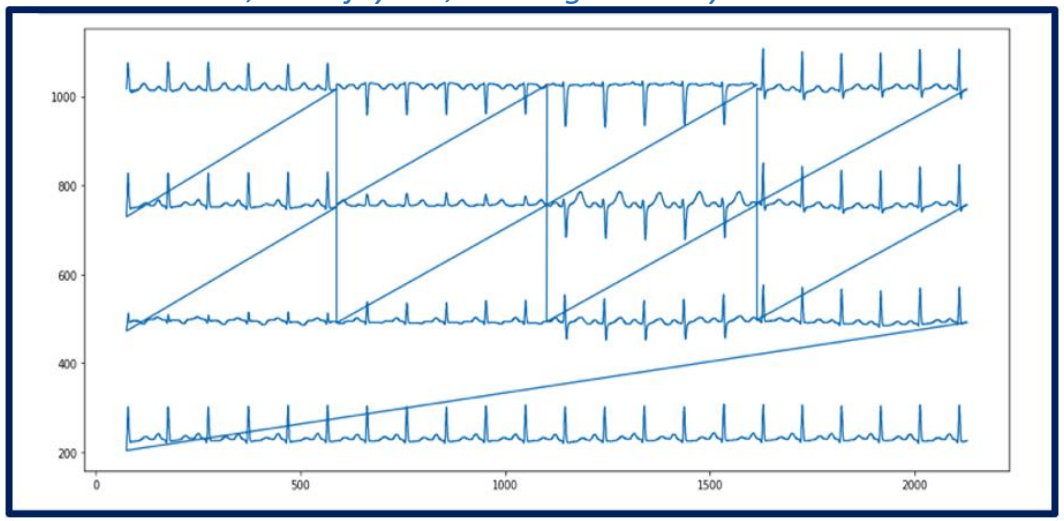


Figure 2: Converted ECG Image from the .csv (tabular format) – (x, y) coordinates of Figure 1

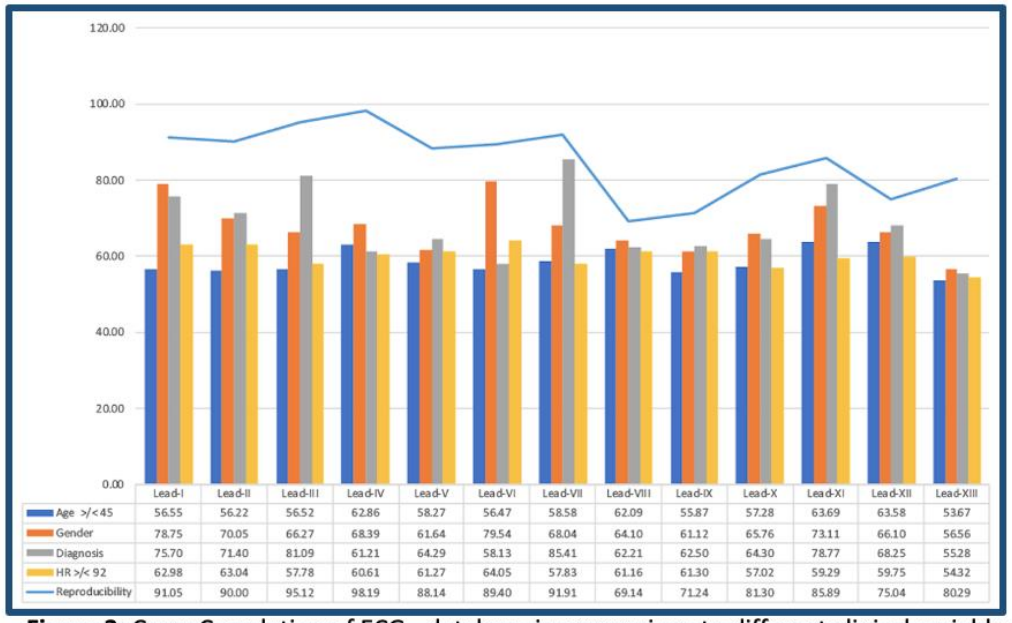


Figure 3: Cross Correlation of ECG - database in comparison to different clinical variables, showing consistency with ECG Reproducibility using DICOM to .csv conversions.

Category	Age >/< 45	Normal / Abnormal	Gender	Heart Rate >/< 90/min
Lead-I	0.46	0.79	0.4	0.5
Lead-II	0.58	0.9	0.47	0.56
Lead-III	0.52	0.7	0.69	0.57
Lead-IV	0.63	0.72	0.62	0.53
Lead-V	0.7	0.86	0.48	0.68
Lead-VI	0.66	0.72	0.62	0.54
Lead-VII	0.56	0.77	0.62	0.58
Lead-VIII	0.72	0.8	0.59	0.59
Lead-IX	0.65	0.85	0.42	0.65
Lead-X	0.61	0.79	0.66	0.72
Lead-XI	0.53	0.74	0.62	0.7
Lead-XII	0.46	0.76	0.61	0.56
Lead-XIII	0.72	0.8	0.65	0.64

Figure 4: Lead wise AUC scores for different clinical variables with definite higher scores for clinical categories (normal vs abnormal) comparing to others

Apollo Throughput Optimisation (TOps Algorithms)

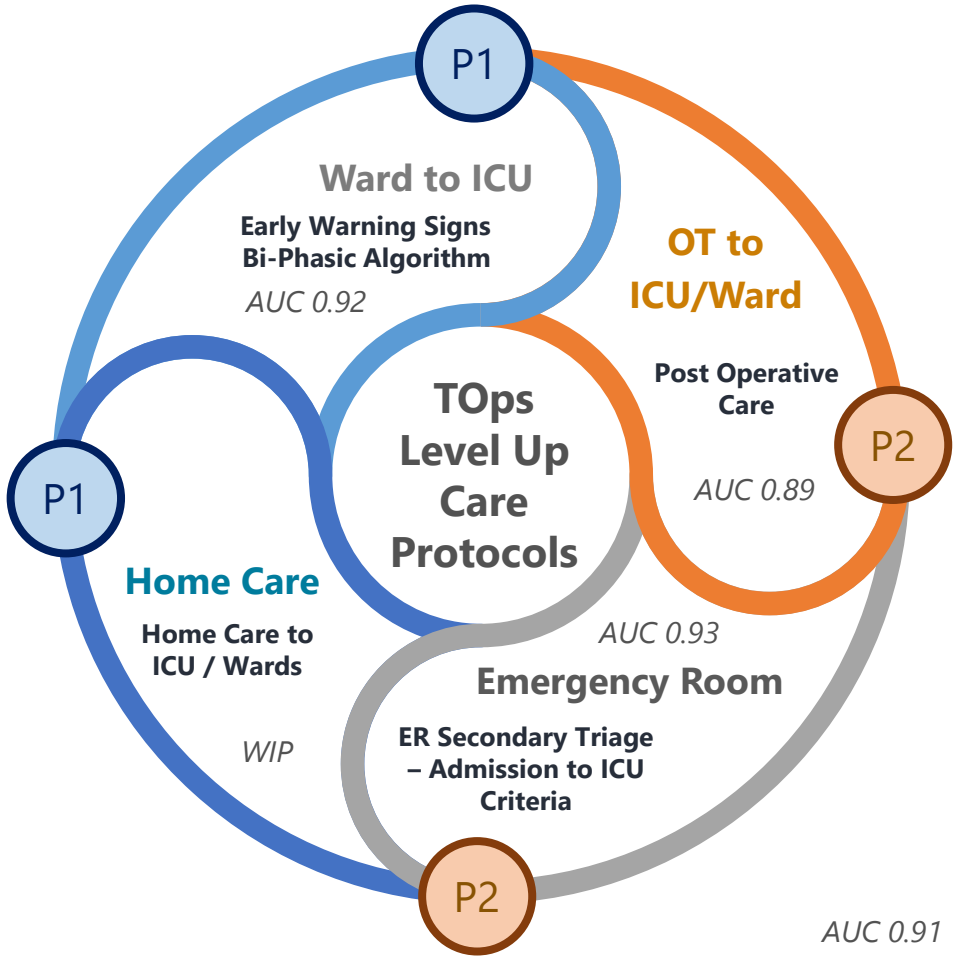
Level Up Clinical Protocols

	Pre-Anesthesia Algorithm	Early Warning Systems Wards / Telemetry	ER Triage to ICU	Discharge in 24/48 hours
Clinical Needs	• Risk Assessment tool for surgeries • Estimates surgical duration, blood loss and post operative patient placement	• Tool to help recognize early signs of clinical deterioration and trigger more intensive care • Prediction of Mortality | Risk Stratification | SHAP values | Advice for monitoring	• Identifies patient that could possibly transfer to ICU from ER • Risk of mortality in next 7 to 28 days	• Predicts probability of patient discharge in the next 24/48 hours • Use of Generative AI + Differentiated Database in building Discharge Summaries
Design & Development	• 347K Surgeries • 8 locations • 500+ surgery types over 18 months	• 145K Critical Patient (Anonymized) Data • Biphasic Model - Vitals + Clinical Features + Lab Data = XGBoost + Nested BERT	• Identifies patient that could possibly transfer to ICU from ER – Over 5K Data • Prototype Research - https://www.nature.com/articles/s41598-021-92146-7	• Collaborative Model with leading Organization • 160K Patient Data • Business Process Re-engineering
Ground Truth	Accuracy – **89%** + R^2 **= 0.51**	Accuracy – **92%**	Accuracy - **93%**	Accuracy - **93%**
Impact	Improved OT Scheduling*	Remote Health Monitoring*	> 10K Risk Stratified (COVID)	ALOS Reduction* Improved Discharge Processes*

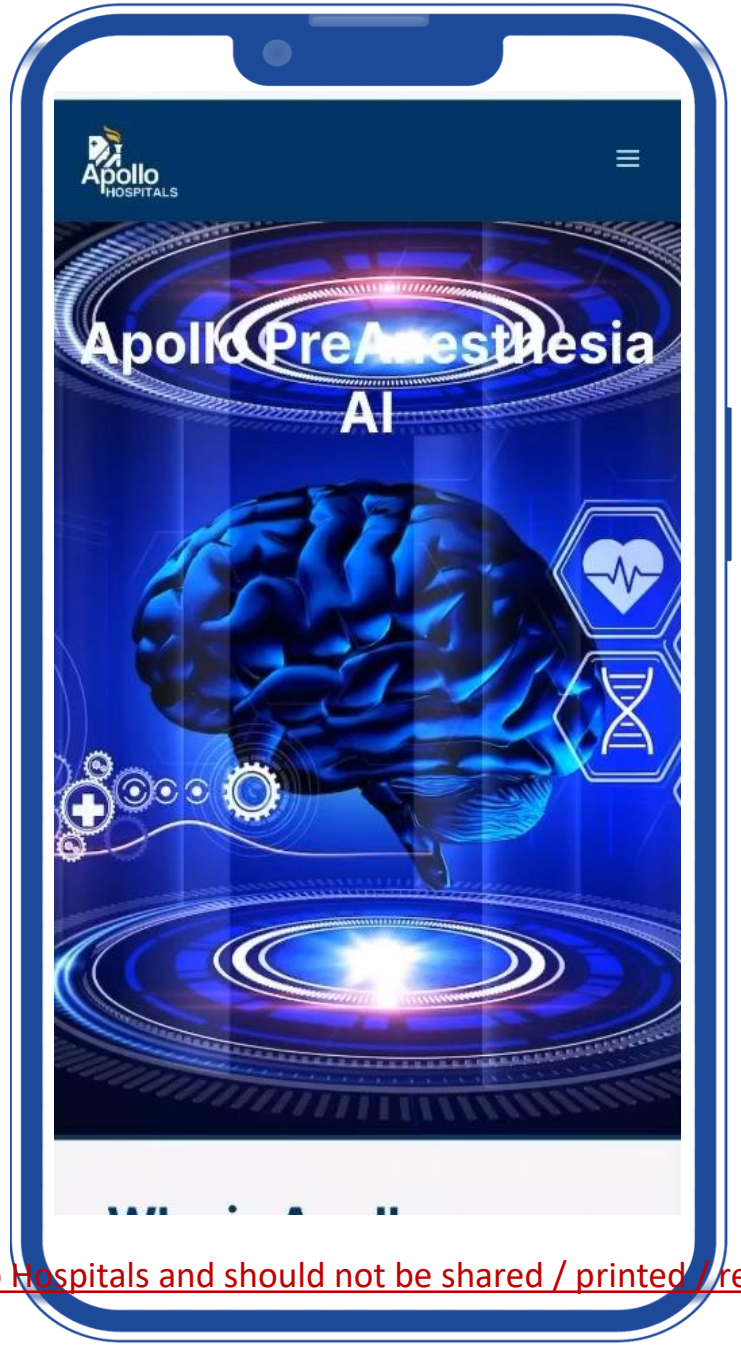
* Ongoing Prospective Use

Throughput Optimization

Pre-Anaesthesia Algorithm



D24 & D 48 hours / Mortality Predictions



Empirical Antibiotic Recommendation System (Apollo EARS)

AI augmented Pathways

Challenges

How to aid the doctors in selection of ideal antibiotic

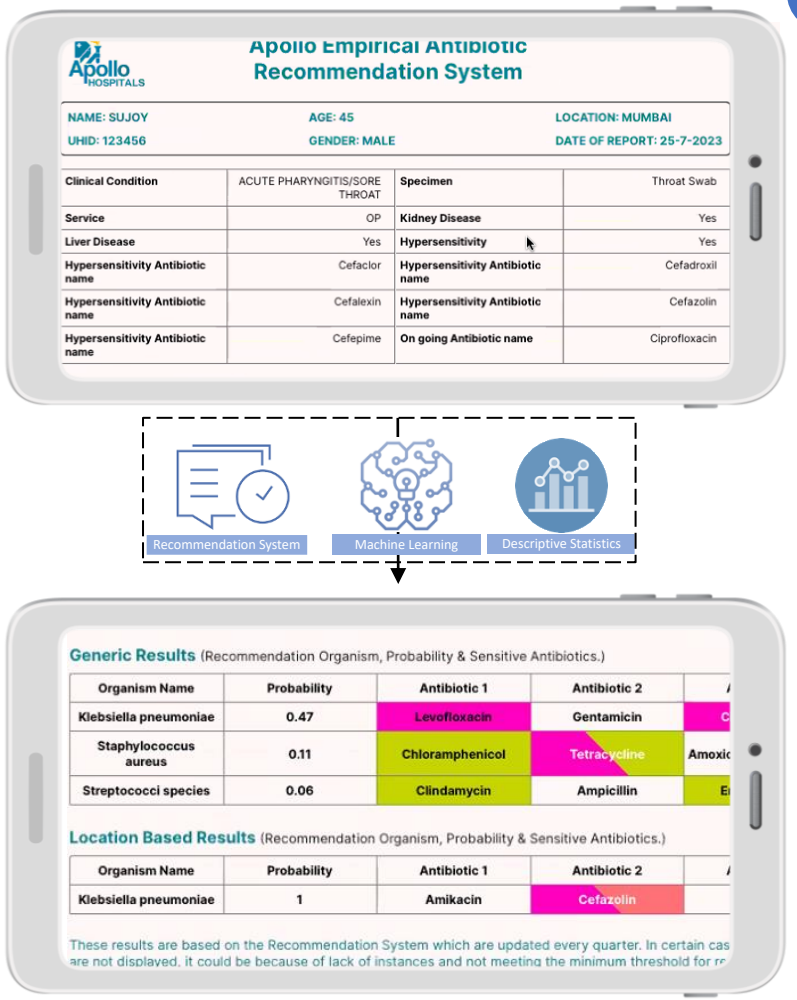
Detect, Respond, and Contain Resistant Pathogens

Patient factors and history could differ, which needs to be considered

Analytics Insights

- Hospital Acquired Infections
- Community Acquired Infections

Solution



Ground Truth

- Provides an accurate Empirical Antibiotic Recommendation for the Physician at point of care
- Yields 3 top probable organisms in the sample collected with corresponding antibiotic sensitivities

Impact

- 7 Apollo Hospitals Prospective Roll Out
- Outcome Accuracy of >80% with change of Antibiotics in 15K Cohort

Key Highlight

Accuracy

87%

The program currently covers:

260K+ Isolates

57 Specimen types

181 Organisms

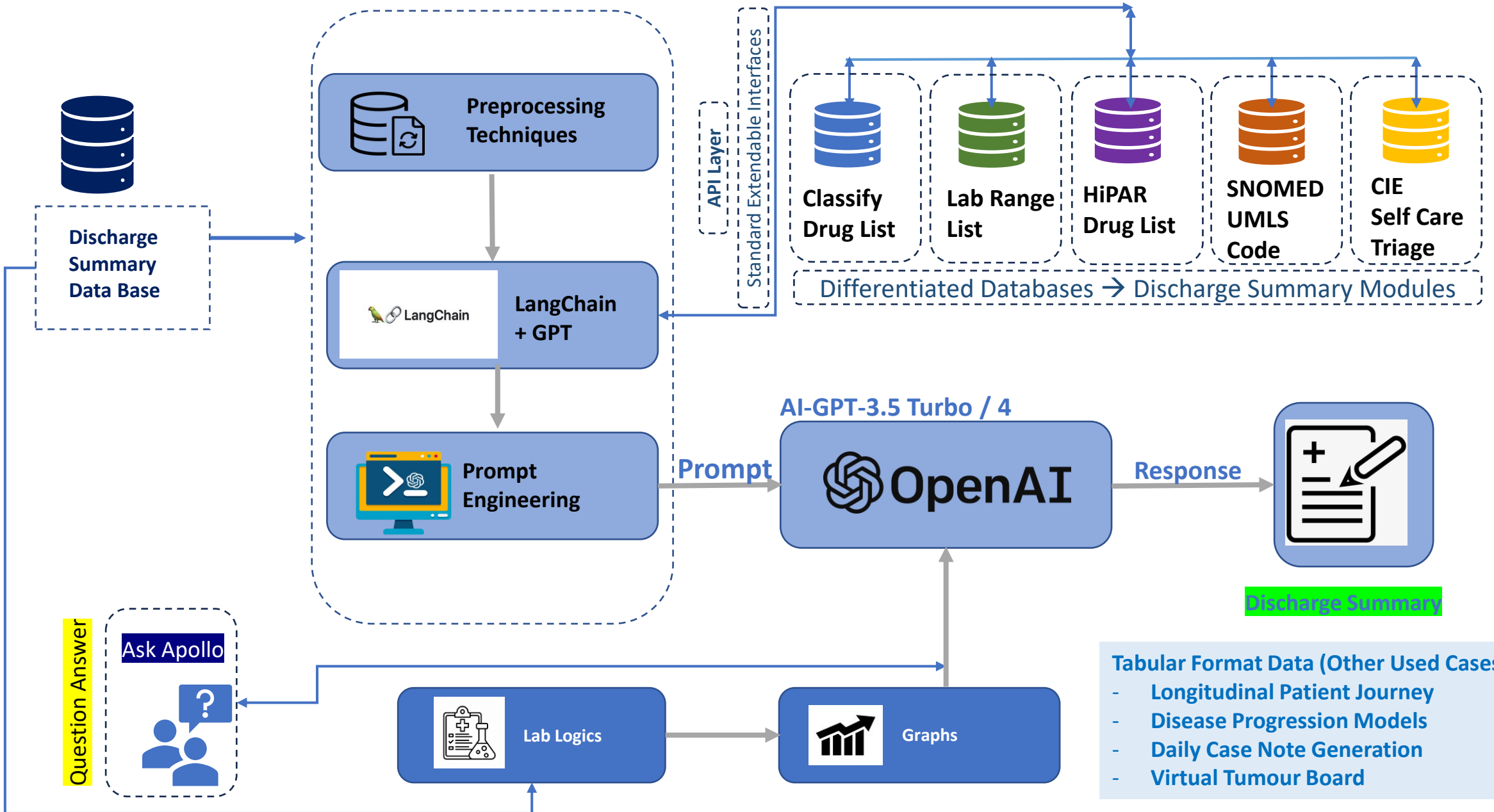
152 Antibiotics

20+ Hospitals

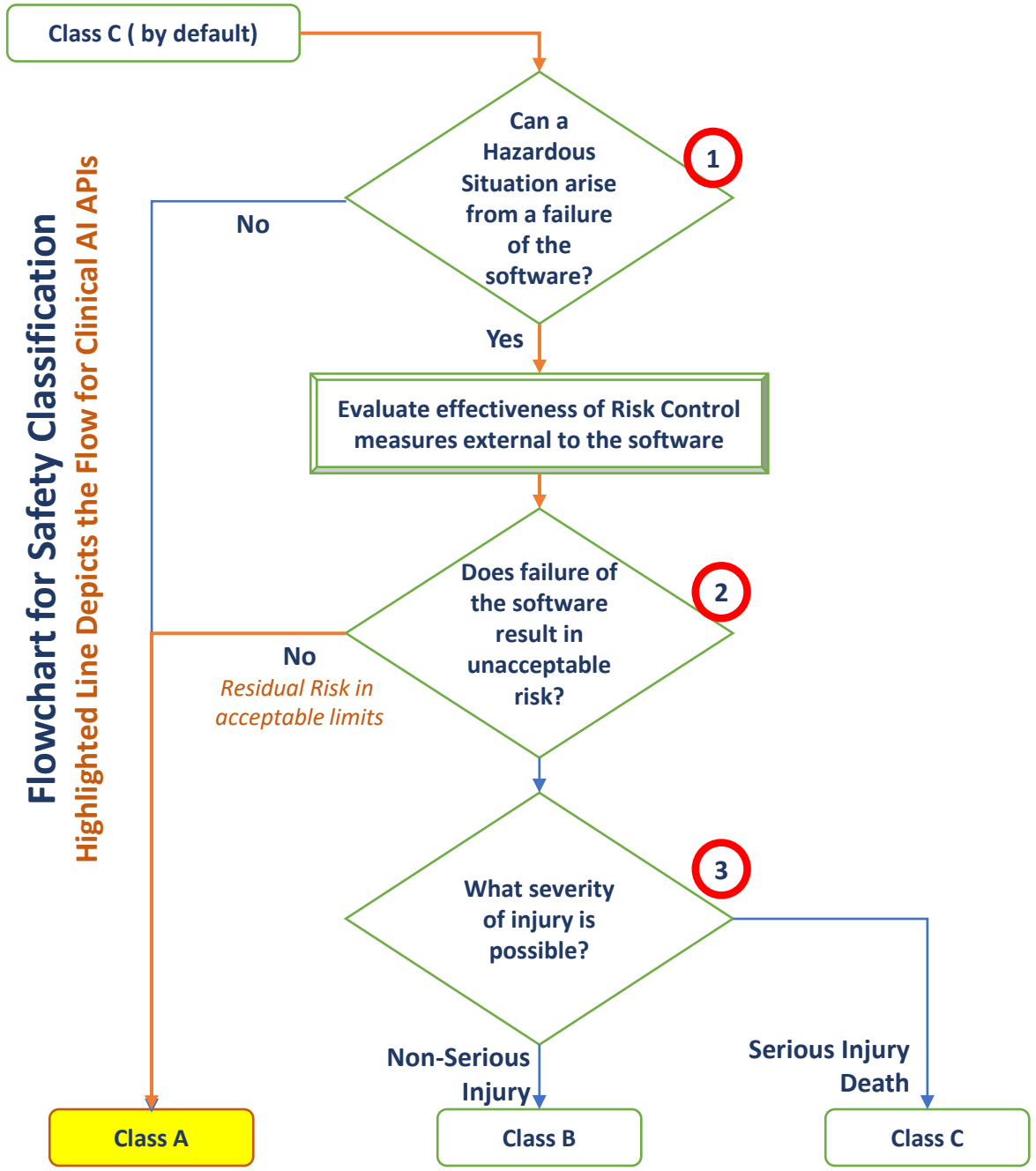
4+ Years (Since 2019)

Country wide Prospective Cohorts with **20** Renowned Specialists

Using GPT : Architecture for Unit Discharge Summary Generation



IEC 62304 Process – Safety Classification of Clinical AI API



bsi.

By Royal Charter

Apollo HOSPITALS

Certificate of Registration

QUALITY MANAGEMENT SYSTEM - ISO 13485:2016

This is to certify that:

Apollo Hospitals Enterprises Limited
Road No. 72
Film Nagar, Opposite Bharatiya Vidya Bhavan School
Jubilee Hills
Hyderabad,
Telangana
500 096
India

Holds Certificate Number: **MD 763515**

and operates a Quality Management System which complies with the requirements of ISO 13485:2016 for the following scope:

The Design, Development and Deployment of Artificial Intelligence based Application Programming Interfaces (APIs) for providing information by means of Clinical Decision Support for Cardiovascular Diseases, Prediabetes & Diabetes, Liver Fibrosis, Empirical Antibiotic Recommendation and Acute Exacerbation of COPD & Asthma.

For and on behalf of BSI:

Gary E Slack, Senior Vice President - Medical Devices

Original Registration Date: 2022-02-28
Latest Revision Date: 2022-02-28

Effective Date: 2022-02-28
Expiry Date: 2025-02-27

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