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
With the combined power of Apollo Hospitals, India’s largest integrated healthcare system...

A 40-year legacy of transforming healthcare

- 73 Hospitals
- 11,000+ Beds
- 1570 Diagnostic Centres
- 200 Telemedicine Centres
- 500 Clinics
- 500+ Clinical Trials

Apollo 24/7

Largest omnichannel healthcare platform in India

- 700+ Collection Centres
- 6,000+ Doctors
- 12,500+ Pharma SKUs

We have delivered exceptional care over the past 4 decades...

- 200Mn Lives Impacted
- 17Mn+ Tele-Consults
- 8 Accredited hospitals

Apollo 24/7

- 23Mn+ Registrations
- 700K+ Daily Active Users
- 35K+ Daily Rx orders

INSTITUTES OF TRANSPLANT
Busiest Solid Organ Transplant Program in the world since 2012

EMERGENCY
Early innovator on tech across the patient value chain

- 500K+ Emergency calls served in 10+ years
- First combined Elective Caesarean and Robotic Assisted Radical Nephrectomy
- First and largest Artificial Pulmonary Valve implanted without surgery
- First bone marrow transplant for Baby with a novel mutation in blood

Among countless other firsts...
What will you do today... to transform the healthcare of tomorrow?
Data Engineering Technologies On Use of Generative AI + Machine & Deep Learning Work

- **Entity Recognition**: Identifying clinical entities in vast and diverse dataset
- **Entity Disambiguation**: Associating the clinical entities with different codes and clinically relevant classification (medication + lab results)
- **Assertion**: Identifying where in clinical data there are negation and over emphasizing a clinical term or decision
- **Relation Extraction**: Identifying relations between two clinical entities, identifying their correlations and merging different datasets to stitch the context
- **Question & Answers**: Developing prompt methodologies to question about care directly to clinical database & get curated answers on diagnosis and treatment
- **Anonymization**: Ensuring no Personal Identifiable Information and there in text of tabular formats of the data
- **Differentiated Database**: Medications, Lab Logic, Self-Care, Triage, Pathways, Knowledge Base, HiPAR
- **Language Translation**: For Self-Care portion of discharge summaries

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DICOM Encapsulated ECGs

Importance of ECG Data
ECG (Electrocardiogram) is a fundamental diagnostic tool in Cardiology. It records the electrical activity of the heart and helps in diagnosing various heart conditions. In the digital age, the need to store, retrieve, and analyze ECG data efficiently is paramount. DICOM provides a standardized format for medical images, including ECGs, ensuring interoperability and data integrity.

Storing and Retrieving DICOM Encapsulated ECGs
DICOM allows for the encapsulation of ECG data, enabling healthcare organizations to store and manage ECGs alongside other medical imaging data. This standardized format ensures data consistency and simplifies data management.
• DICOM headers store patient information, acquisition details, and more.
• Encapsulated ECGs can be linked to patient records for easy retrieval.

Challenges and Opportunities While storing and retrieving DICOM encapsulated ECGs is essential, the real power lies in leveraging this data for improved patient care. Machine learning offers exciting opportunities for analysis and prediction based on ECG data.

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**Objective**

#1 - Machine picks from an ECG  
(As per Standard Communication Protocol) —  
- HFrEF/HFpEF/HFmrEF (Abnormal) vs Normal ECG  
  (Propensity Matched)  
- Differences in the wave / rhythm / rate patterns of HFrEF-HFpEF-HFmrEF vs Normal ECG  

#2 - Attributes for Heart Failure LLM  
1) **Echo - EF – >45% Ejection Fraction**  
2) Current Clinical Data - NYHA – Upgrade  
   (Clinical Data) – Vitals + Comorbidities  
3) Lab Marker – raised enzyme levels (pro BNP)  
4) Medications  
5) Revisit Longitudinal Data  

End Goal is for AI Model for Predicting HFpEF in next 5 years  
Risk of HFpEF in 1, 2, 3 & 5 Years  

Clinical Decision Support  
Lifestyle Modification  
Heart Failure Registry
HF Study
ECG Conversion

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We have been able to convert the whole ECG to near accuracy in tabular format. We have developed this as a home-grown API and converted at least 10K of Longitudinal Normal ECGs vs Abnormal ECGs (Heart Failure) – which is used to predict HF detection. The hazard model (time to event) model (predicting future heart failures) is in pipeline.
HF Study
ECG Conversion – Predicting Accuracy in Categories

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10K+ | Preliminary XGB Classification Model on different Intervals in ECG

Abnormal records: 23%

Input Parameters : - X Parameters used: 'Age', 'Gender', 'PR', 'PQ', 'PT', 'PS', 'QRS', 'QT', 'ST', 'RR', 'PP', 'QQ', 'SS', 'TT', 'Heart Rate'.

Output Parameters : Y : Normal(0) & Abnormal(1)

Accuracy: 0.91 | ROC AUC: 0.86
Precision: 0.82 | Recall: 0.78 | F1 Score: 0.80
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ECG Conversion – Architecture for Unit ECG LLM Generation

HF Study

API Layer

Preprocessing Techniques

LangChain + Vector DBs

Prompt Engineering & finetuning

Classify Drug List

Lab Range List

ECG Logic List

Heart Failure Pathways

CIE Self-Care Triage

ECG Reports Database

Prompt

OpenAI

Azure-open AI-GPT-4

Clinical Decision Support
Lifestyle Modification
Heart Failure Registry

Question Answer

Medmantra CRM

Lab Logics

Graphs

Standard Extendable Interfaces

Differentiated Databases → Heart Failure Summary Modules
AI based Disease Progression & Risk Score Models
Deployment – Calibrate – Redesign - Redeploy

Value Capture: Deployment

“FOR ALL THE TIMES YOU’VE HAD MY BACK.”

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## Apollo Throughput Optimisation (TOps Algorithms)

### Level Up Clinical Protocols

<table>
<thead>
<tr>
<th>Clinical Needs</th>
<th>Pre-Anesthesia Algorithm</th>
<th>Early Warning Systems</th>
<th>ER Triage to ICU</th>
<th>Discharge in 24/48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Risk Assessment tool for surgeries</td>
<td>• Tool to help recognize early signs of clinical deterioration and trigger more intensive care</td>
<td>• Identifies patient that could possibly transfer to ICU from ER</td>
<td>• Predicts probability of patient discharge in the next 24/48 hours</td>
</tr>
<tr>
<td></td>
<td>• Estimates surgical duration, blood loss and post operative patient placement</td>
<td>• Prediction of Mortality</td>
<td>• Risk of mortality in next 7 to 28 days</td>
<td>• Use of Generative AI + Differentiated Database in building Discharge Summaries</td>
</tr>
<tr>
<td></td>
<td>• Prediction of Mortality</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Design & Development

<table>
<thead>
<tr>
<th></th>
<th>347K Surgeries</th>
<th>145K Critical Patient (Anonymized) Data</th>
<th>160K Patient Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 locations</td>
<td>500+ surgery types over 18 months</td>
<td>Business Process Re-engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biphasic Model - Vitals + Clinical Features + Lab Data = XGBoost + Nested BERT</td>
<td>Collaborative Model with leading Organization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prototype Research - <a href="https://www.nature.com/articles/s41598-021-92146-7">https://www.nature.com/articles/s41598-021-92146-7</a></td>
<td>160K Patient Data</td>
</tr>
</tbody>
</table>

### Ground Truth

<table>
<thead>
<tr>
<th></th>
<th>Accuracy – 89% + R² = 0.51</th>
<th>Accuracy – 92%</th>
<th>Accuracy - 93%</th>
<th>Accuracy - 93%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>Improved OT Scheduling*</td>
<td>Remote Health Monitoring*</td>
<td>&gt; 10K Risk Stratified (COVID)</td>
<td>ALOS Reduction*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improved Discharge Processes*</td>
</tr>
</tbody>
</table>

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* Ongoing Prospective Use
Heart Failure Registry

IMAGE ANALYTICS: DESIGNING THE ECG STORAGE, AI-ML WORK IN HEART FAILURE
CONCEPT DESIGN – HEART FAILURE INNOVATION CAPSULE

Heart Failure Business Case
- Collect data from multiple patients/scenarios:
  * Episodes ID, date in/out, inpatient/outpatient, acute/non-acute, diagnosis codes during episodes (ICD), procedure codes during episodes (ICD), age, gender, costs registered during episodes
  * Tune the predicting models to obtain an accurate business case for the heart failure workflow along with a sensitivity analysis

Outcomes: Predictive models based on complex algorithms to streamline HF care delivery | Risk stratification | Readmission rates reduction
- Methods:
  * Proactive diagnosis/risk scoring
  * Control over outcomes
  * Risk stratification
  * Patients discharge streamlined

Predictive Health Analytics Modeling

Mapping Of The Patients Stakeholders
- Identifying the owners of the patient at the different stages
- Identifying what should be coordinated within the hospital
- Multidisciplinary steering committees
- Collaboration/education among colleagues (workshops, lectures, training courses, information sessions, etc.)

Outcomes: Better planning and coordination
- Lower costs for the clinics
- Safer and more involved families
- Lower flexible staffing
- Optimize bed planning
- Improved patient quality of life

Care Workflow/Registry Development
- Review of care programs, and update referral paths
- Development of digital referral tools
- Manage resource allocation: • Optimal use of facilities • Optimal use of experts
- Creation of a patient flow manager

Outcomes:
- Reduced acute and emergency room visits
- More accessible healthcare for patients (visits, phone, or videoconference)
- Stronger network around the patient through close collaboration with clinics

An efficient bridge between inpatient and outpatient care where patients with heart failure who had just been released quickly get the specialized care they need

Building Capability for Heart Transplant
- Respiratory Clinics – COPD / ILD – for Heart Lung Transplant
- Liver Clinic
- End Stage Renal Disease Clinic
- Breast & Lung Cancer Clinics

Heart Failure Clinic Day/Home Care Bridge

Export Heart Failure Clinic Model

VII HF Innovation Capsules

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How is the experience with Generative AI???

1. DIFFERENTIATED DATABASES
   Generative AI in Healthcare is as good as curated content that you can build & provide as prompt.

2. PROMPT BRITTLENESS
   Variation in Prompt Syntax – change in wording, ordering, or selection of examples – make it unpredictable & unreliable.

3. HALLUCINATION
   Fluent and Natural generated texts which are unfaithful and / or undetermined.
Thanks

Any Questions?