Introduction.

AICVD Cardiac Risk Score is a novel artificial intelligence based risk score system that provides the individual's risk of having Coronary Artery Disease related events in the next 10 Years. The risk score is developed by Apollo Hospitals with further validation from National and International institutions. The methodology helps to stratify the patients risk and provide individualised protocol using a Clinical Decision Support System on next best actions with an accuracy above 90%

Why is AICVD different ?

1. Machine Learning Model developed with Indian Data having Higher Accuracy than conventional risk score
    a. Cox Proportional Hazard Model + Deep Learning Classification Model
    b. Model Built and Validated with Over 400K Patient data since 2008
    c. Accuracy - AUC – 0.86 (Development) and 0.92 (Validation) Cohort
2. Feedback Loop from the prospective use in patients
3. Comprehensive & Holistic Risk Assessment
4. Validated at different National & International Institutions
5. Integrated Clinical Decision Support Tool (What Next to do)

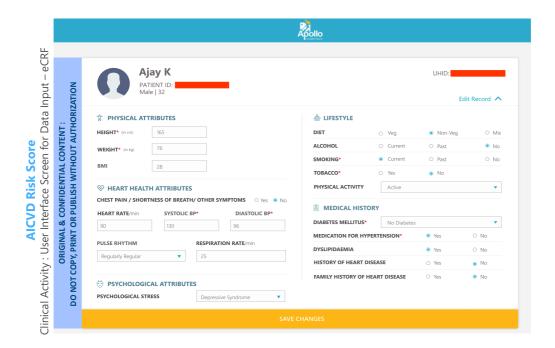Interpretation & Adoption Message

1. AI Algorithm + Clinicians - This Risk Assessment tool has been built as an adjunct tool for the physicians to identify the global / holistic risk for the patient
2. Risk Identification and Prevention - This Risk Assessment Tool is not to be used for diagnosis of Coronary Artery Disease. Its limitations include already diagnosed Cardiovascular Disease and currently under treatment.
3. Where to use - This Risk Assessment tool has been prepared for use at Preventive Cardiology Screening programs at the Outpatient Clinics and for Health Check Clinics

How to Use (For Clinicians Only) –

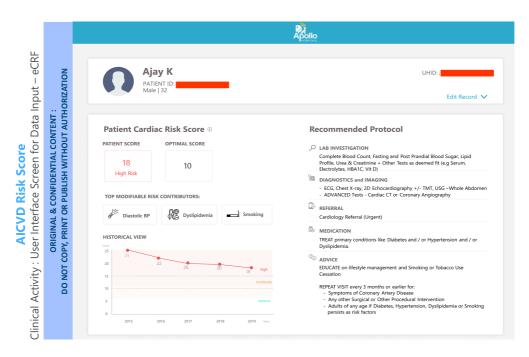1. Provide Appropriate –
    a. Demographic Details
    b. Obtain Patient Consent

2. Risk Factors Included –
    a. Personal/VS – Age | Gender | Height | Weight | BMI
    b. Life Style Attributes - Diet | Alcohol | Smoking | Tobacco Use | Physical Activity
    c. History - Family History | Previous CAD | Dyslipidemia* | Diabetes mellitus* | Hypertension* (*Diagnosis or Medication)
    d. Heart Related Attributes - Heart Rate | Systolic BP | Diastolic BP | Cardiac Symptoms | Rhythm | Respiratory Rate New! – Psychological Stress

3. Output
   a. Risk Categorization
   b. Cardiac Risk Score and Optimum Risk Score for Individual Age / Gender
   c. Top Modifiable Risk Attributes
   d. Clinical Decision Support System (What Next to do)
       i. Lab, Imaging and Investigations
       ii. Cardiology Referral
       iii. Treatment Goals
       iv. Education
       v. Revisit Guidelines

Printed Report

AICVD RISK SCORE REPORT

NAME: Sujoy	AGE: 46	LOCATION: Hyderabad
UHID: 123456	GENDER: Male	DATE OF REPORT: 14/9/2021

Informed Consent

Physical Attributes:
Height: 170
Weight: 85
Bmi: 29.41
Psychological Stress: Anxiety Syndromes

Heart Health Attributes:
Heart Rate: 90
Systolic Bp: 120
Diastolic Bp: 80
Respiration Rate: 12
Pulse Rhythm: Regularly Regular
Chest Pain / Shortness of Breath/ Other Symptoms: No

Life Style:
Diet: Mix
Alcohol: No
Smoking: No
Tobacco: No
Physical Activity: Active

Medical History:
Diabetes Mellitus: Controlled with medication
Medication For Hypertension: Yes
Dyslipidaemia: No
History Of Heart Disease: No
Family History Of Heart Disease: No

Patient Cardiac Risk Score

RISK CATEGORY	PATIENT SCORE	OPTIMAL SCORE
Moderate Risk	8	6

Top Risk Contributors

bmi	Physical Inactivity	Hypertension

Recommended Protocol

LAB INVESTIGATION
Complete Blood Count, Fasting and Post Prandial Blood Sugar, Lipid Profile, Urea & Creatinine + Other Tests as deemed fit (e.g. HBA1C) Homocysteine Levels Lipoprotein a Neutrophil / Lymphocyte Ratio

DIAGNOSTICS AND IMAGING
ECG, Chest X-ray, 2D Echocardiography, Dobutamine Stress Echo TMT

REFERRAL
Cardiologist Referral (Routine)

TREATMENT PROTOCOL
Weight control management
It is recommended to consistently encourage weight control through an appropriate balance of physical activity, caloric intake, and formal behavioural programmes when indicated to achieve and maintain a healthy BMI (<25)
Lipid management: To maintain a baseline. Annual control of lipids, glucose metabolism and creatinine are recommended.
Diabetes: HbA1c < 7% (< 53 mmol/mol).
Blood pressure control : < 140/90 mmHg
Smoking / Tobacco Use cessation: No exposure to tobacco in any form or support in smoking cessation.
Psychosocial management: Psychosocial risk factor screening should be considered

4. Disclaimer
   a. This is not a diagnostic tool and it does not guarantee the accuracy of the result and cannot be independently acted upon.

b. This Risk score and Clinical Algorithm is a general guideline for Physicians. Any additional laboratory investigations, Diagnostic Imaging, Treatment or Patient Education related to lifestyle management is under Physician's or Cardiologist's discretion.

c. To ensure the information in the report is up to date, accurate and correct, Doctor shall be consulted for interpretation of the report.

d. Apollo Hospitals and its Staff does not offer any assurance on the information made available or be liable for any loss or damage as the said report is based on the AICVD Cardiac Risk Score without any intervention from their side.

e. By usage of AICVD Cardiac Risk Score, it is deemed that beneficiary of this service has agreed to get the same done at his own risk and further agrees with this disclaimer without any limitation or any clauses or sub-clauses.

Research

Cardiovascular diseases (CVD) are one of the most prevalent diseases in India amounting for nearly 30% of total deaths. Dearth of research on CVD risk scores in Indian population, limited performance of conventional risk scores and inability to reproduce the initial accuracies in randomized clinical trials – has led to this study on large-scale patient data. Objective is to develop an Artificial Intelligence based Risk Score (AICVD) to predict CVD Event (e.g. Acute MI / ACS) in next 7 years and compare the model with Framingham Heart Risk Score (FHRS) and QRisk3.

Study included 31,599 participants aged 18-91 years from 2010-2017 in six Apollo Hospitals in India. A multi-step risk factors selection process using Spearman correlation coefficient and propensity score matching yielded 21 risk factors. Deep Leaning Hazard Model was built on risk factors to predict event occurrence (classification) and time to event (hazard model) using multi-layered neural network. Further, the model was validated with independent retrospective cohorts of participants from India and the Netherlands and compared with FHRS and QRisk3.

The performance of the Deep Learning Hazard model was at AUC 0.853. Validation and comparative results showed AUCs between 0.84 to 0.92 with better Positive Likelihood Ratio (AICVD-6.16 to FHRS– 2.24 and QRisk3–1.16) and Accuracy (AICVD– 80.15% to FHRS 59.71% and QRisk3 51.57%). In the Netherlands cohort, AICVD AUC outperformed Framingham Heart Risk Model (0.737 to 0.707).

The study concludes that the novel AI based CVD risk score improves on accuracy and precision of prediction than conventional risk scores.

Ethics Perspectives

Title	Development and Validation of Multicenter Study on Novel Artificial Intelligence Based Cardiovascular Risk Score (AICVD)	Centers	India – Apollo Hospitals in Delhi, Kolkata, Hyderabad, Bangalore, Chennai and Mumbai King George Medical Univ. Lucknow Maastricht Univ. The Netherlands
Principal Investigators	Dr Shivkumar J (Apollo Hospitals), Prof Andre Dekker (Maastricht UMC), Prof Rishi	Institutional Ethics Committee Approval	All Centres between Sept 2018 to Nov 2019 and annually followed. CTRI Registration – done

	Sethi (KGMU, Lucknow), Dr Sujoy Kar (Apollo Hospitals)		Microsoft Aether (Ethics) approved
Data	Retrospective – Prospective Jan 2008 to June 2018 September 2019 Onwards	Safety	Model advocates risk scores that are interpreted by clinicians through safe Machine (API) – Human (Clinician) Interaction
Sample Size + Missing Data	31599 + 3246 (Validation) + 1340 (KGMU) + 12588 (MUMC) No imputations	Inclusiveness & Fairness	At admission data includes clinical comorbidities & conditions	No socioeconomic discrimination
Personal Health information	De-identified all PHI during analysis, model building, API hosting and Prospective Use	Privacy & Confidentiality	Data secured at Apollo Azure Tenant with all relevant compliance + conforming to laws
Addressing Bias (Geographical / Ethnic / Temporal / Gender etc.)	Multiethnic – All Adult Population Group – Male to Female – 55 : 45 – Time Period – Jan 2008 to June 2018 Automation Bias addressed at API Clinical Use	Accuracy + Efficacy	Classification Metrics - sensitivity: 0.83	specificity: 0.9	Accuracy Score : 0.87
Risk Groups	Low – Moderate – High Risk of CVD	Informed Consent	Yes – Template & Protocol (Prototype Attached)
Model Specification	Cox Proportional Hazard + Deep Learning + Hazard Ratio + KM Plots	API – Ease of Use + Interpretation	Flows to Clinical Algorithm Standard Clinical Definitions + Lab Units Used
Clinical Algorithm Update (Version)	Version 3 – February 2021	Validation + Peer Review	American College of Cardiology Lancet Open Source BMJ Open – Under Review

Patient appropriate for SCREENING or with symptoms
21 Clinical Parameters (API)

Patient Parameters	Medical History	Lifestyle	Heart Health Attributes
Age	Hypertension	Diet	Heart Symptom
Gender	Diabetes mellitus	Alcohol	Heart Rate
Height	Dyslipidemia	Smoking	Systolic BP
Weight	History of Heart Disease	Tobacco	Diastolic BP
BMI	Family History of Heart Disease	Physical Activity	Pulse Rhythm
			Respiration Rate

Generate Cardiac Risk Score

<1 of Optimum Score	1- 1.5 of Optimum Score	>1.5 of Optimum Score
Minimal Risk	**Moderate Risk**	**High Risk**

<1 of Optimum Score — Minimal Risk

Referral : None

Lab Investigation
Complete Blood Count, Fasting Blood Sugar, Lipid Profile, Urea & Creatinine

Diagnostics & Imaging
ECG, Chest X-ray
2D Echocardiography

Medication
TREAT primary conditions like Diabetes or Hypertension and / or Dyslipidemia

EDUCATE on lifestyle management and Smoking or Tobacco Use Cessation

REPEAT TESTING **every year** for:
– All adults age ≥45 **OR**
– Adults of any age if Diabetes, Hypertension, Dyslipidemia or Smoking persists as risk factors

1- 1.5 of Optimum Score — Moderate Risk

Referral : Cardiologist (Routine)

Lab Investigation
Complete Blood Count, Fasting and Post Prandial Blood Sugar, Lipid Profile, Urea & Creatinine + Other Tests as deemed fit (e.g. HBA1C)

Homocysteine Levels
Lipoprotein a
Neutrophil / Lymphocyte Ratio

Diagnostics & Imaging
ECG, Chest X-ray,
2D Echocardiography
Dobutamine Stress Echo
TMT

Medication
TREAT primary conditions like Diabetes and / or Hypertension and / or Dyslipidemia
Medical Treatment (Prevention) of Coronary Artery Disease

EDUCATE on lifestyle management and Smoking or Tobacco Use Cessation

REPEAT VISIT **every 6 months** or earlier for:
– Adults of any age if Diabetes, Hypertension, Dyslipidemia or Smoking persists as risk factors
– Symptoms of Coronary Artery Disease
– Any other Surgical or Other Procedural Intervention

>1.5 of Optimum Score — High Risk

Referral : Cardiologist (Urgent)

Lab Investigation
Complete Blood Count, Fasting and Post Prandial Blood Sugar, Lipid Profile, Urea & Creatinine + Other Tests as deemed fit (e.g. HBA1C)

Homocysteine Levels
Lipoprotein a
Neutrophil / Lymphocyte Ratio
hsCRP

Diagnostics & Imaging
ECG, Chest X-ray,
2D Echocardiography,
Dobutamine Stress Echo
TMT

ADVANCED Tests -
Cardiac CT or Coronary Angiography
Thallium Stress Test

Medication
TREAT primary conditions like Diabetes and / or Hypertension and / or Dyslipidemia
Intervention or Medical Treatment of Coronary Artery Disease

EDUCATE on lifestyle management and Smoking or Tobacco Use Cessation

REPEAT VISIT **every 3 months** or earlier for:
– Symptoms of Coronary Artery Disease
– Any other Surgical or Other Procedural Intervention
– Adults of any age if Diabetes, Hypertension, Dyslipidemia or Smoking persists as risk factors