# Survival and Prediction of Heart Disease Events

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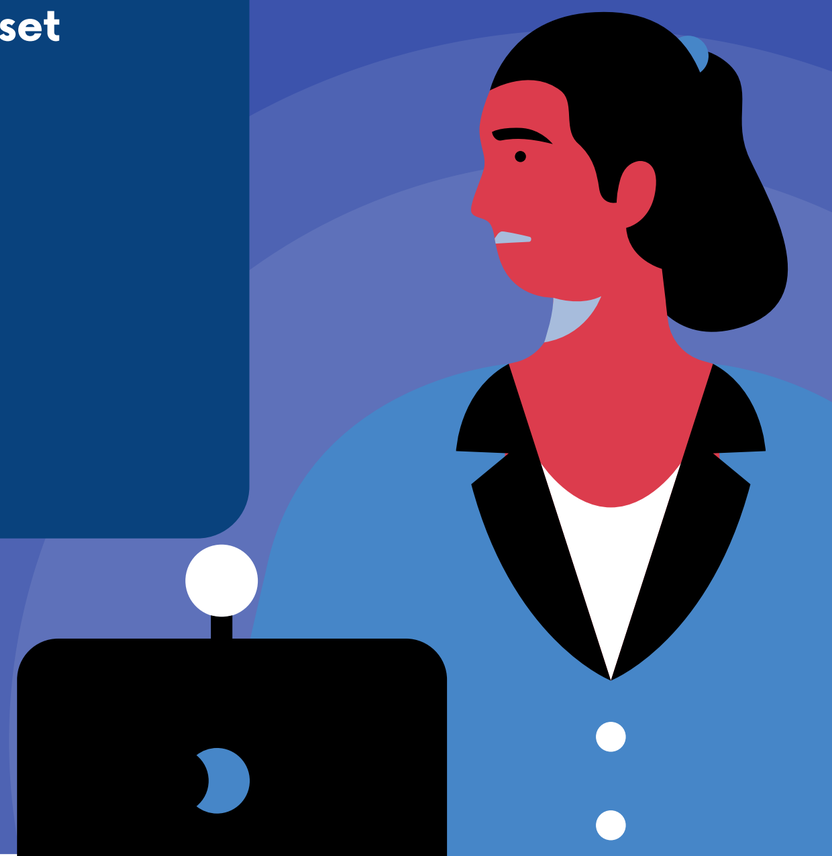


# What is Coronary Heart Disease?

**Coronary Heart Disease**

HD develops when main arteries become clogged and start to harden and narrow. Untreated CHD may result in patients developing Heart Failure.

**Coronary Angiography**

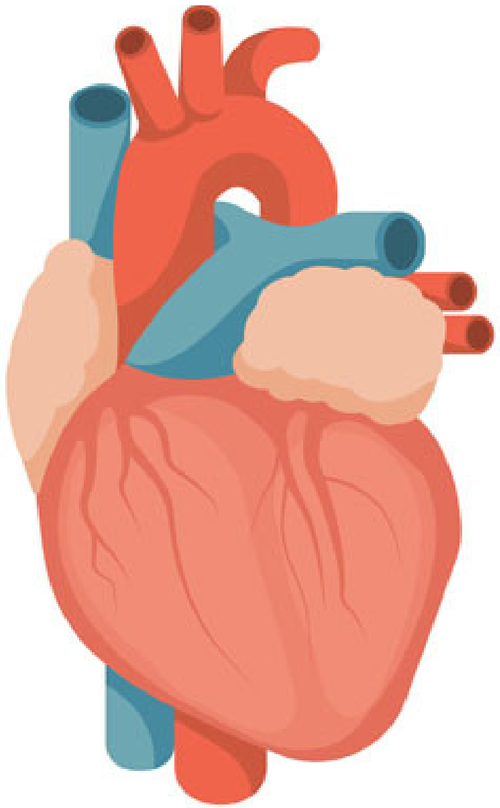
Angiography is an invasive medical procedure that uses contrast die and x-ray in order to visualize the inside of blood vessels and detect blockages in the main arteries.

**When to do Coronary Angiography**

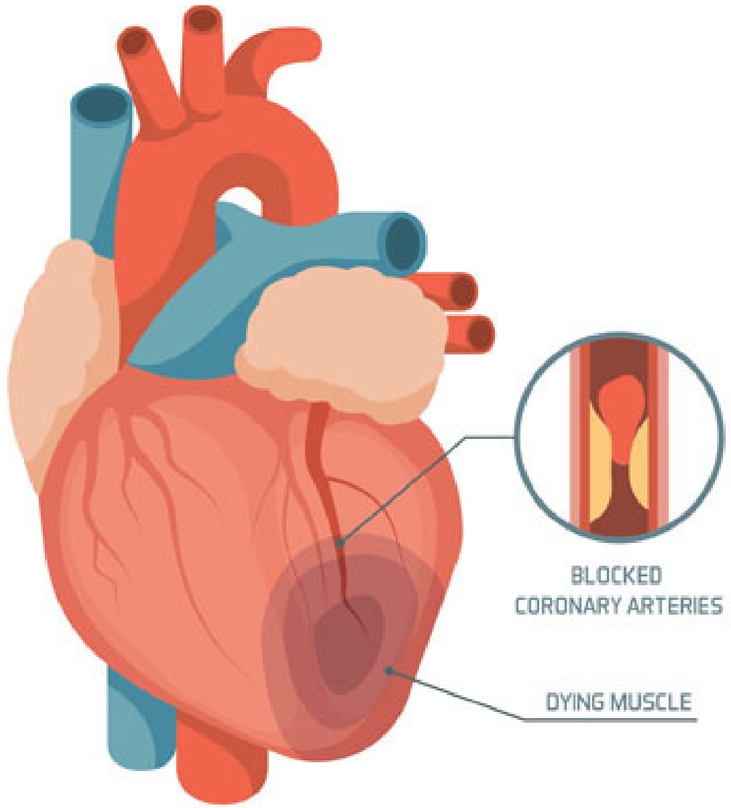
Your doctor may recommend it when you have increasing chest pain or other blood vessel problems.

# What is Heart Failure?

Heart failure occurs when the heart is too weak or stiff and is not able to pump enough blood in order to maintain the normal blood flow necessary to meet the body's needs.



HEALTHY HEART




HEART FAILURE

# Questions of interest

Are there variables that can help explain if a patient is at risk of developing coronary heart disease?

How different hospitals may affect the diagnosis of a coronary heart disease?

Once patients have been diagnosed with heart failure, which variables affect their survival? Can those variables successfully predict a death event?

# Coronary Heart Disease Dataset

918 Patients undergoing Coronary Angiography

Coronary angiograms were considered abnormal, i.e. presence of CHD, if there was greater than 50% luminal narrowing of any major arteries

4 Hospitals
- Cleveland
- Hungary
- Long Beach
- Switzerland

**Patient Information**
- Age
- Sex
- Hospital

**Clinical Data**
- Resting Blood Pressure
- Max Heart Rate
- Peak (ST Segement)
- Fasting Blood Sugar
- Resting ECG
- Exercise Angina
- Chest Pain Type

**Outcome of Interest**
**Presensce of Coronary Heart Disease**

# Chest Pain

### Typical Chest Pain

It consists of substernal chest pain or discomfort caused by exertion or stress and relieved by rest.

### Atypical Chest Pain

It applies when not all of the symptoms for typical angina are present and therefore is also called probable angina.

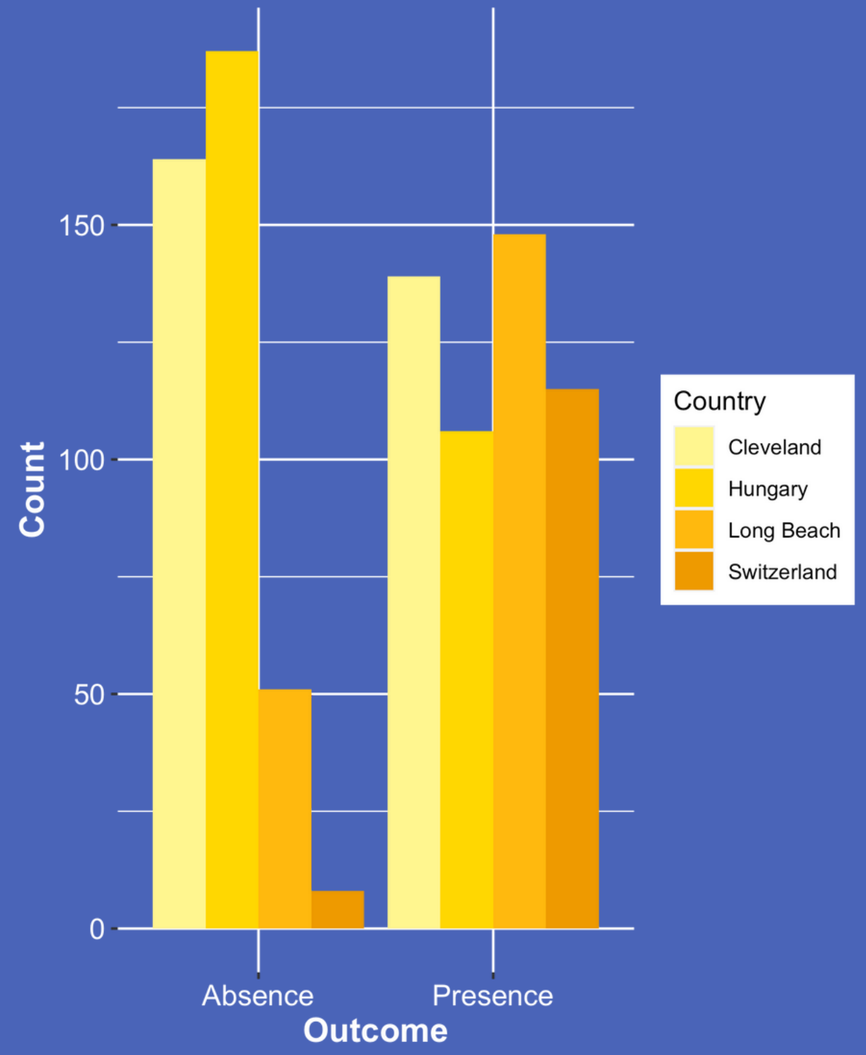
### Non-anginal Chest Pain

It often feels like angina and is usually related to problems with the esophagus, lung conditions or chest bones.

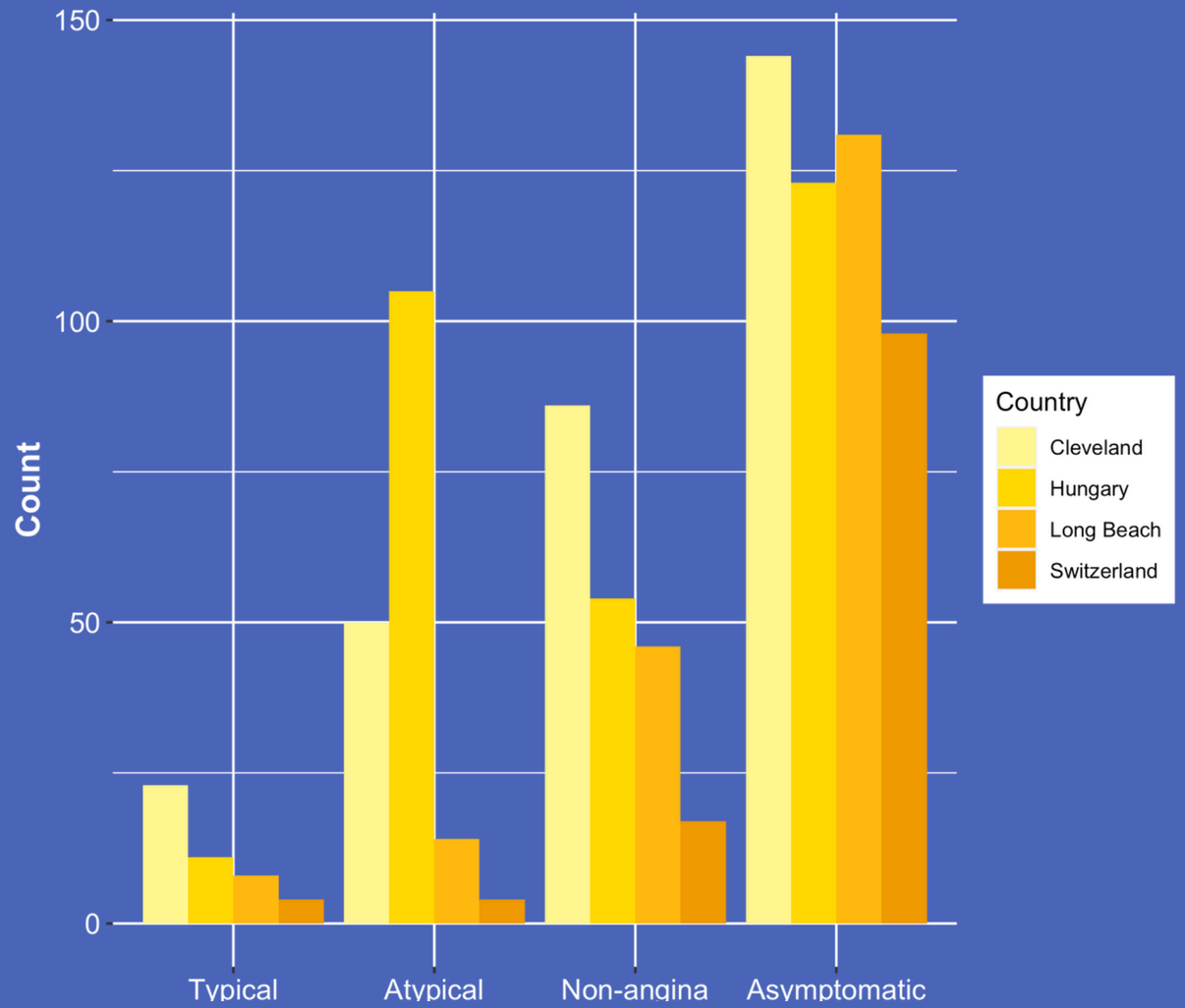
### Asymptomatic

Patients do not feel any chest pain or discomfort. It is often related to silent myocardial infarction which is most likely to occur in middle-aged man.

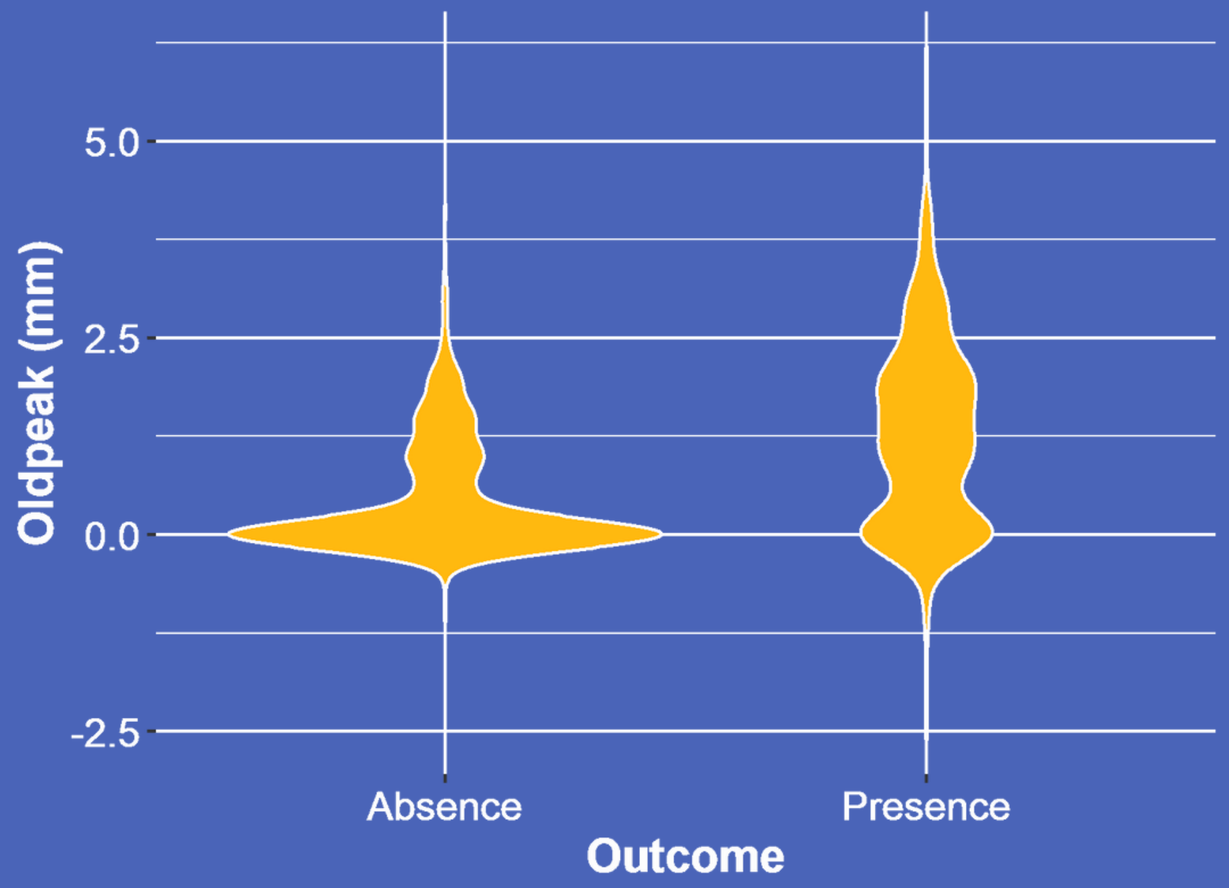
## Presence of Heart Disease by Country




## Chest Pain Type by Country

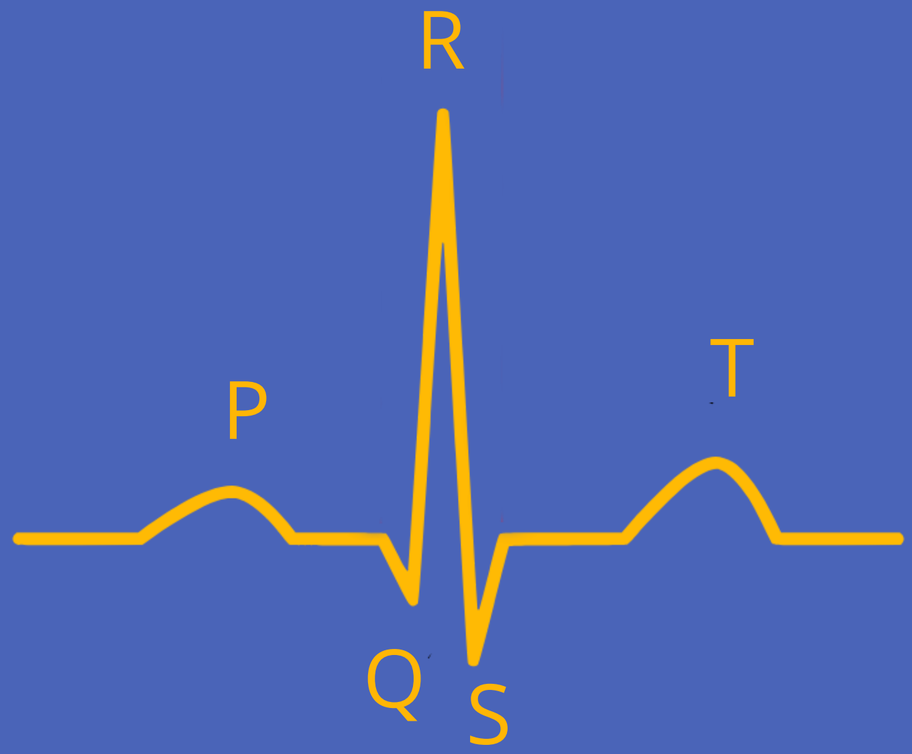


# ST Segment




**ST depression or elevation induced by exercise relative to rest.**

**ST segment as a categorical variable. Values between -1 and 1 are coded as Normal. Otherwise as Abnormal.**



# Generalized Mixed Effects Model

$$logit(p_{ij}) = \beta_0 + \beta 1 MaxHeartRate_{ij} + \beta_2 OldPeak_{ij} + \beta_3 FastingBloodSugar_{ij} + \beta_4 ExerciseAngina_{ij} + \beta_5 Age_{ij} + \beta_6 Sex_{ij} + \beta_7 ChestPain_{ij} + b_j \qquad b_j \sim N(0, \sigma_b^2)$$

$$i = 1, 2, ..., 918$$

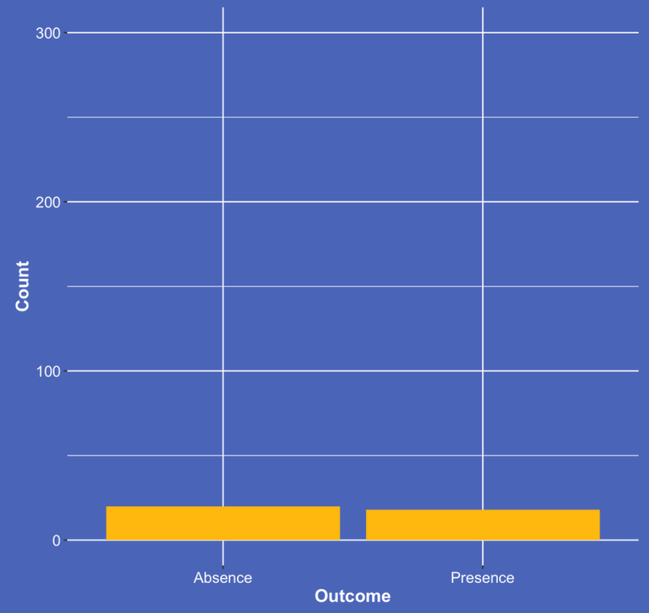
$$j = 1, 2, 3, 4 \; Countries$$

| Variable | Estimate | CI Lower | CI Upper | Exponential |
|---|---|---|---|---|
| **Intercept** | -0.496 | -2.751 | 1.758 | - |
| **Max Heart Rate** | -0.011 | -0.019 | 0.002 | 0.989 |
| **Peak** (Abnormal) | 1.084 | 0.682 | 1.486 | 2.956 |
| **Fasting Blood Sugar** (High) | 0.657 | 0.147 | 1.167 | 1.929 |
| **Exercise Angina** (Yes) | 0.990 | 0.587 | 1.393 | 2.691 |
| **Age** | 0.029 | 0.006 | 0.052 | 1.029 |
| **Sex** (Male) | 1.278 | 0.805 | 1.751 | 3.589 |
| **Chest Pain** (Presence) | -1.713 | -2.081 | 1.344 | 0.180 |

**Protective Factor**

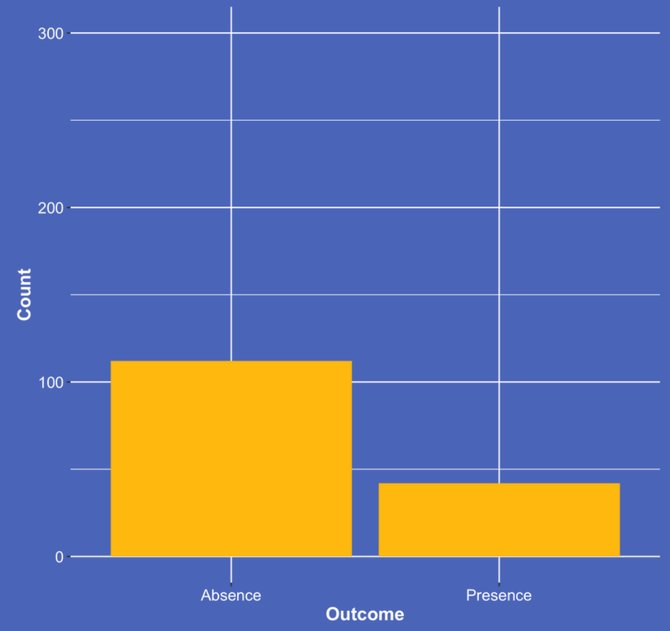
**Risk Factors**

**Protective Factor**

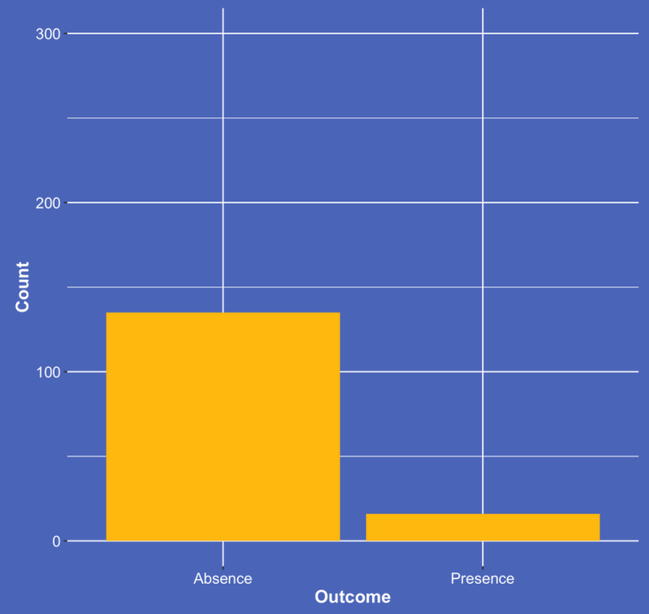



No Exercise Angina and Typical Angina Chest Pain

No Exercise Angina and Non-angina Chest Pain

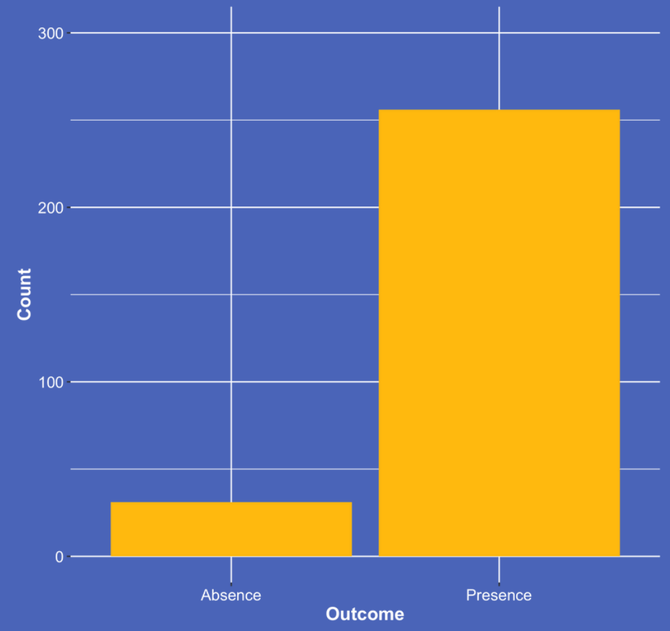



## Chest Pain Protective?

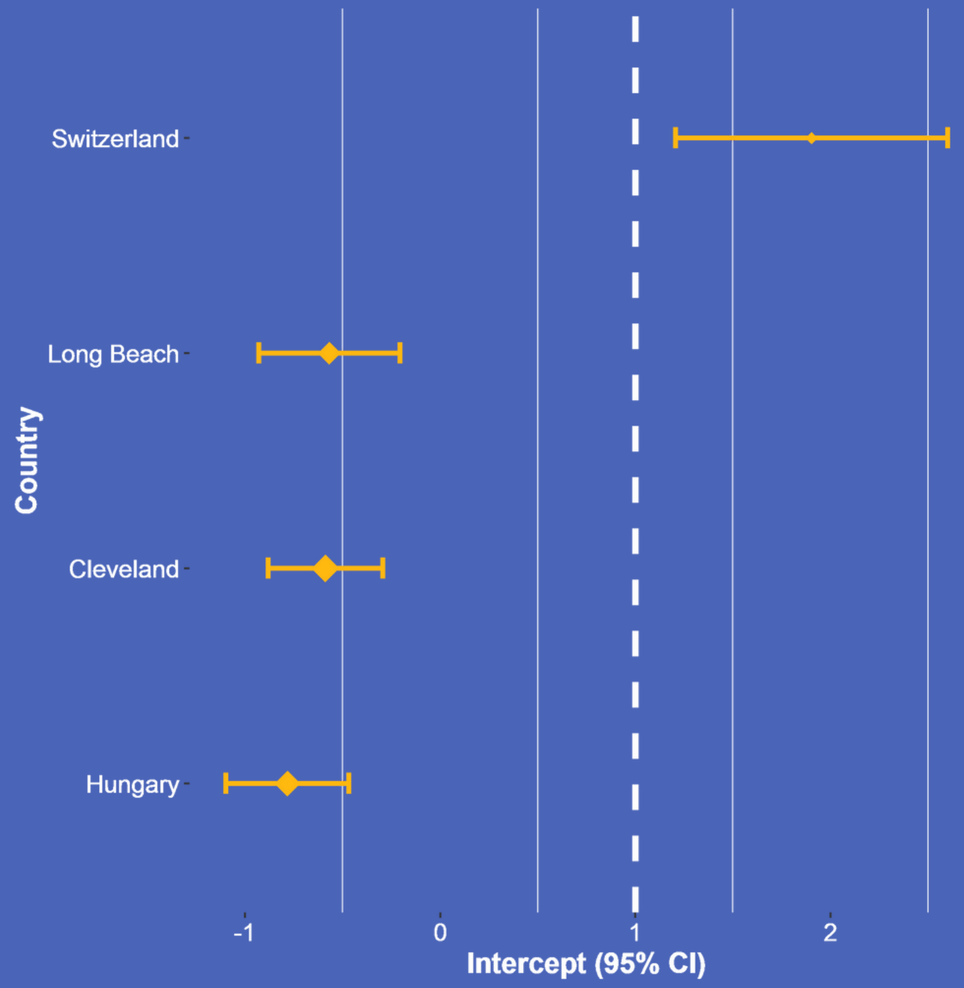



No Exercise Angina and Atypical Chest Pain

Exercise Angina and No Chest Pain



# Variability between Countries




Random Effect

**VPC = 28.5%**

**As shown in the plot, there is a huge variability between the countries.**

**Data from Switzerland suggests there may be a difference in protocols as to when the coronary angiography should be carried out.**

It has been shown how some features  (exercise angina, ST segment) explain the risk of having coronary heart disease.

But in many cases, patients are not diagnosed with coronary heart disease until they have a heart failure due to the possible lack of classic symptoms.

Heart failure represents one of the most common complications of heart disease. Narrowed arteries may limit your heart's supply of oxygen-rich blood, resulting in weakened heart muscle.

# Heart Failure Dataset

299 Patients suffering from Heart Failure

Faisalabad Institute of Cardiology
Allied Hospital in Faisalabad
(Pakistan)

**Patient Information**

- Age
- Sex
- Smoking
- Diabetes

**Clinical Data**

- Anemia
- Creatinine Phosphokinase
- Ejection Fraction
- Blood Pressure
- Platelets
- Serum Creatinine
- Serium Sodium

**Outcome of Interest**

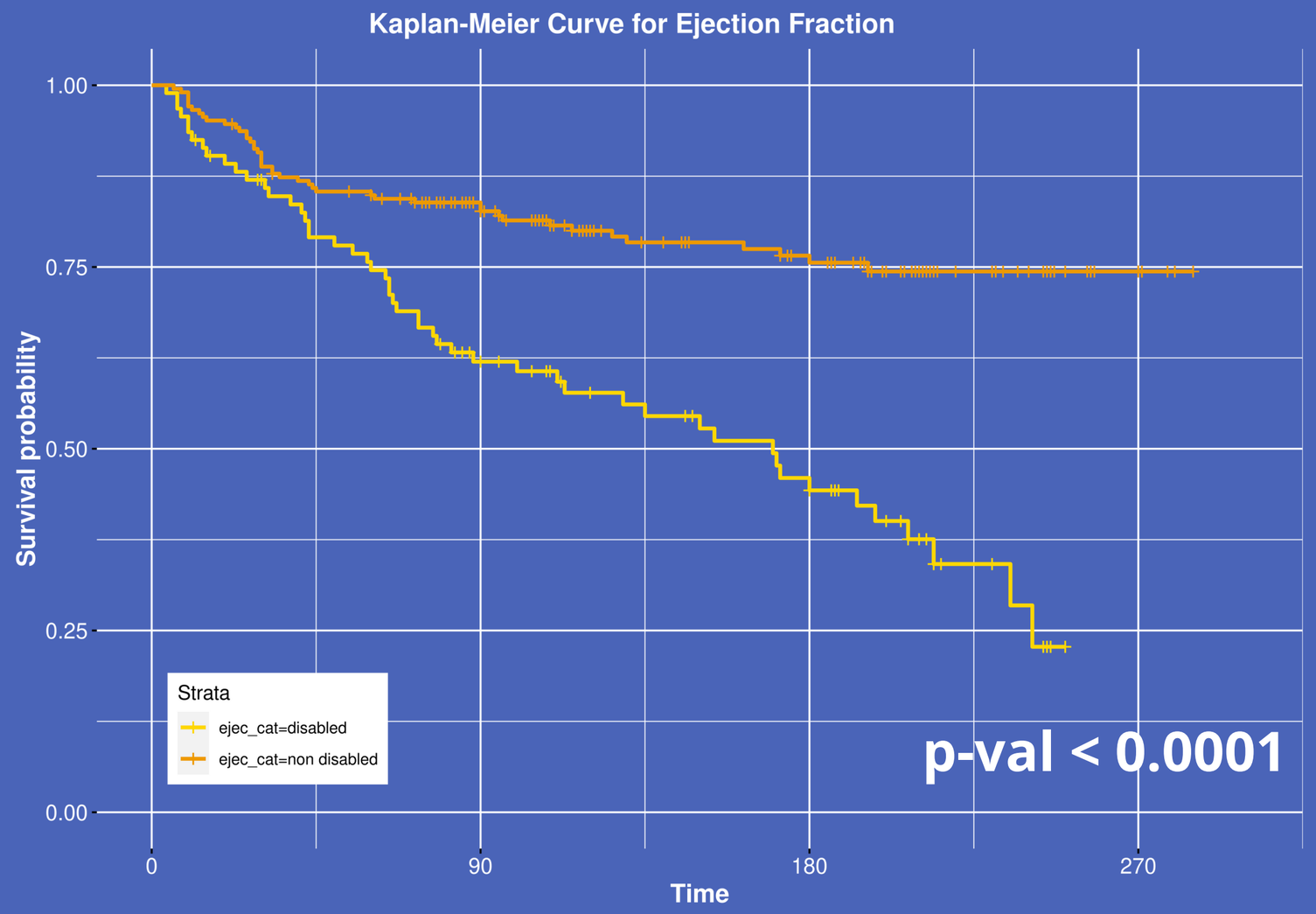
- Death Event
- Time-to-event

# Ejection Fraction

Percentage of how much blood is pumped out of the left ventricle with each contraction. As the heart muscle becomes more stiff and thick, less blood can enter the ventricle.

Reduction of EF is strictly connected to HF
- Normal LVEF >50%
- Reduced LVEF 30%-50%
-Low LVEF <30%

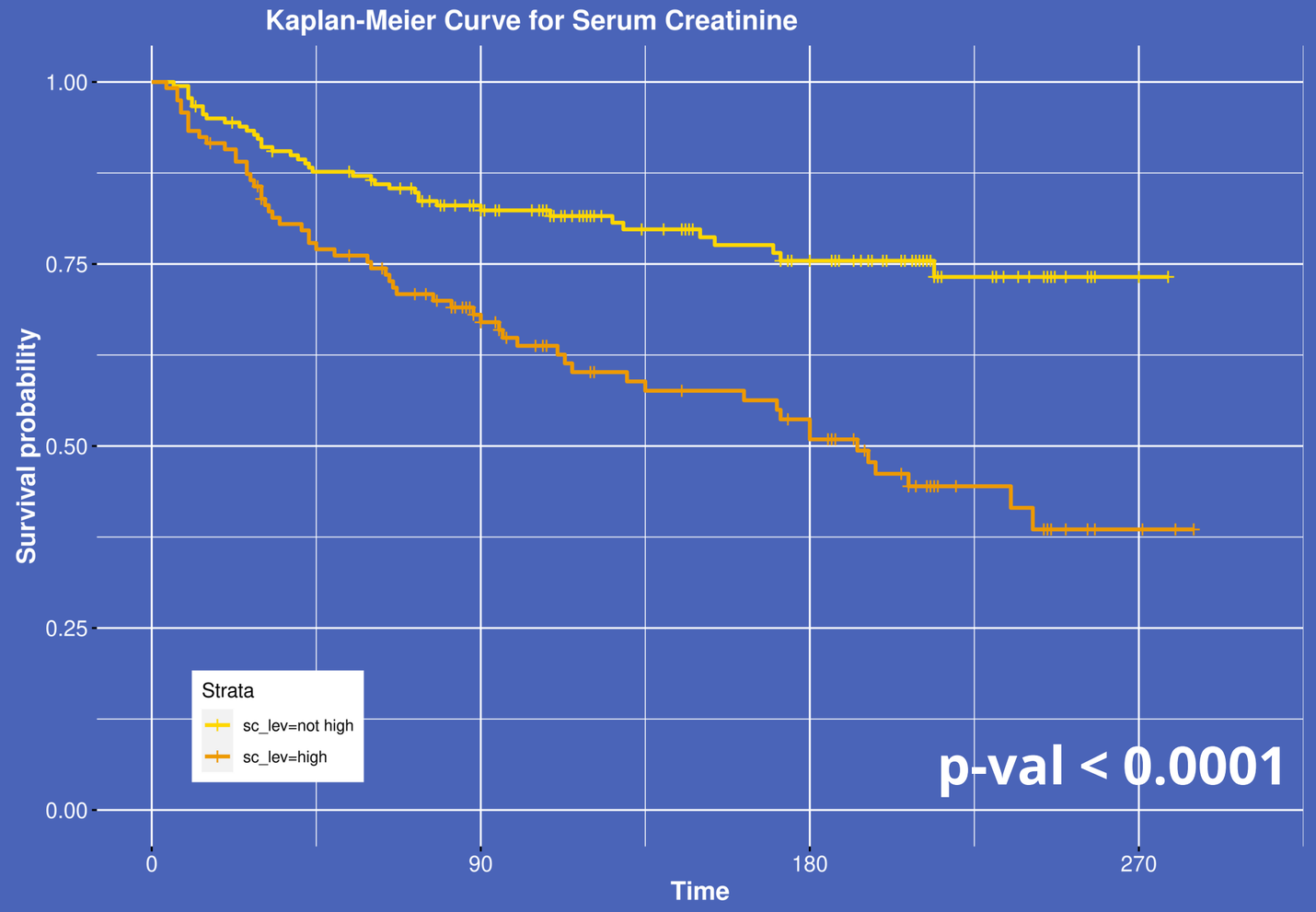
LVEF < 30% is a threshold for disability benefits



# Serum Creatinine Levels

Levels of creatinine in the blood. It is a measure of how well your kidneys are working. Patients with severe heart failure are usaully prescribed ACE inhibitor as medication that can increase SC concentration.

Normal levels for women are 0.5 mg/dL to 1.0 mg/dL
Normal levels for men are 0.7 mg/dL to 1.2 mg/dL .



# Cox Model

| Variable | Hazard Ratio | CI Lower | CI Upper | P-val *Cox.zph()* |
|---|---|---|---|---|
| **Age** | 1.047 | 1.028 | 1.066 | 0.552 |
| **Blood Pressure** (High) | 1.702 | 1.124 | 2.575 | 0.767 |
| **Ejection Fraction** (Low) | 3.041 | 2.001 | 4.623 | 0.002 |
| **Serum Creatinine** (High) | 1.813 | 1.189 | 2.765 | 0.145 |

PH assumption is not satisfied by Ejection Fraction

Two Baseline Hazards for the different levels of Ejection Fraction

# Stratified Cox Model

Risk Factors

| Variable | Hazard Ratio | CI Lower | CI Upper | P-val *Cox.zph()* |
|---|---|---|---|---|
| **Age** | 1.049 | 1.030 | 1.069 | 0.89 |
| **Blood Pressure** (High) | 1.721 | 1.136 | 2.607 | 0.77 |
| **Serum Creatinine** (High) | 1.814 | 1.190 | 2.764 | 0.39 |

# Prediction - Logistic Regression

**Can the variables in the Cox Model be used to determine whether patients diagnosed with heart failure will survive?**

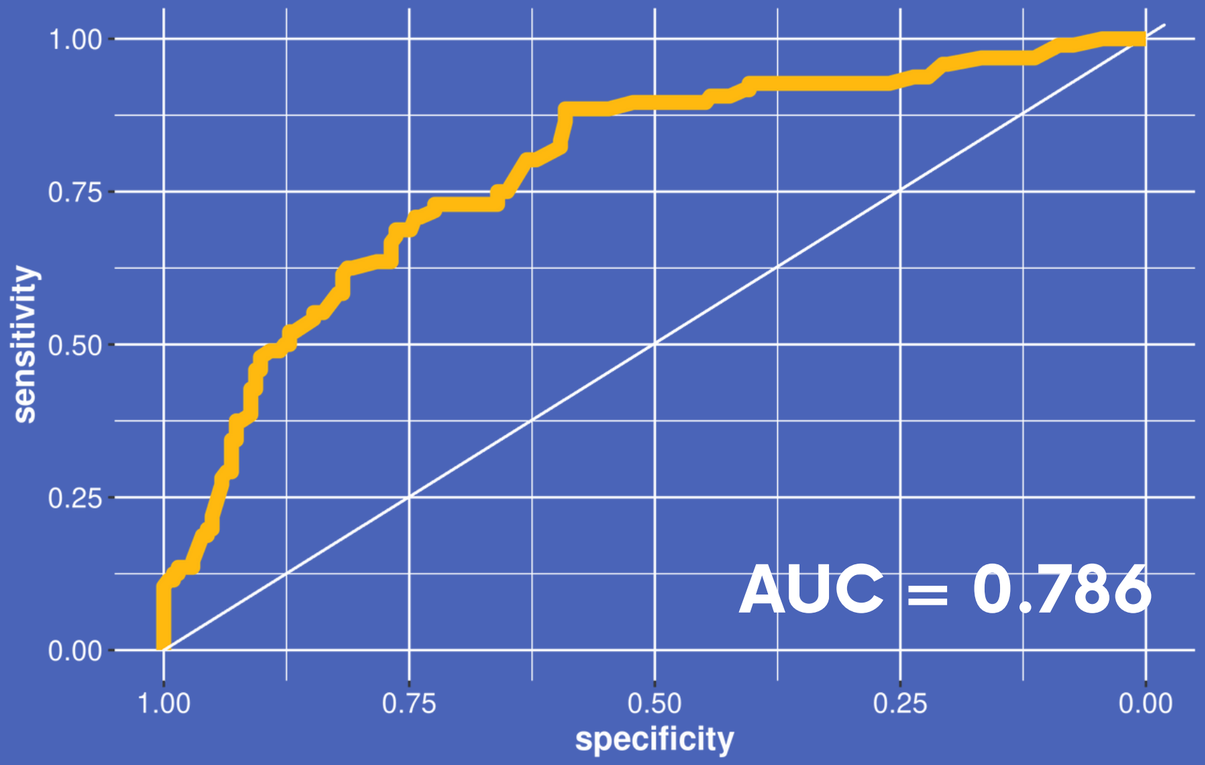
$$logit(p_i) = \beta_0 + \beta_1 Age_i + \beta_2 BloodPressure_i + \beta_3 EjectionFraction_i + \beta_4 SerumCreatinine_i$$

| Variable | Estimate | Odds Ratio | P-value |
|---|---|---|---|
| **Intercept** | -5.255 | - | $7.12 \times 10^{-10}$ |
| **Age** | 0.054 | 1.055 | $1.85 \times 10^{-5}$ |
| **Blood Pressure** (High) | 0.383 | 1.467 | 0.192 |
| **Ejection Fraction** (Low) | 1.642 | 5.165 | $4.84 \times 10^{-8}$ |
| **Serum Creatinine** (High) | 0.985 | 2.678 | $5.4 \times 10^{-4}$ |

**Risk Factors**

# Model Accuracy

**Empirical Threshold = 0.321**




| | Observed Dead | Observed Alive |
|---|---|---|
| Predicted Dead | 68 | 53 |
| Predicted Alive | 28 | 150 |

**Sensitivity = 0.708**
**Specificity = 0.739**
**Accuracy = 0.729**

# Conclusions

- From our analysis, ST segment, Exercise Angina and Fasting Blood Sugar are the main risk factors for developing Coronary Heart Disease.
- The presence of any kind of Chest Pain appears to be a protective factor, suggesting CHD may go unnoticed unless proper tests are carried out.
- There is variability in the outcome between hospitals indicating there may exist a difference in protocols.

- Once patients have been diagnosed with Heart Failure, Serum creatinine levels, Age and High Blood Pressure are the main risk factors that will shorten their survival.
- We have different survival curves for patients with disability benefits, low ejection fraction, and no benefits.

# Thanks for your Attention!