Survival of patients with heart failure

Raj Sharma

2023-11-11

Source of data: UCI machine learning repository:https://archive.ics.uci.edu/dataset/519/heart+failure+clinical+records

Upload date of data: 2nd April 2020

Owner of the data: The original dataset version was collected by Tanvir Ahmad, Assia Munir, Sajjad Haider Bhatti, Muhammad Aftab, and Muhammad Ali Raza in 2015. Current dataset has slight difference from original dataset in terms of names of columns which was done by D. Chicco and Giuseppe Jurman in their article published on BMC Medical Informatics and Decision Making. Link:https://bmcmedinformdecismak.biomedcentral.com/articles/10.1186/s12911-020-1023-5#article-info

Objective of data collection: Dataset was collected for analyzing the survival pattern of heart failure patients who were admitted to Institute of Cardiology and Allied hospital Faisalabad-Pakistan during April-December (2015). And also rank the features which corresponds to the most important risk factors.

Analysis of data by other researchers: D.Chicco and Giuseppe Jurman found in their analysis that serum creatinine and ejection fraction plays a very important role in understanding if a patient will survive after heart failure or not.This discovery has the potential to impact on clinical practice, becoming a new supporting tool for physicians when predicting if a heart failure patient will survive or not.

Description of data set: This dataset was collected during April–December 2015.It contains the medical records of 299 heart failure patients collected at the Faisalabad Institute of Cardiology and at the Allied Hospital in Faisalabad (Punjab, Pakistan). The patients consisted of 105 women and 194 men, and their ages range between 40 and 95 years old. All 299 patients had left ventricular systolic dysfunction and had previous heart failures that put them in classes III or IV of New York Heart Association (NYHA) classification of the stages of heart failure. The dataset contains 13 features, which report clinical, body, and lifestyle information.

Description of columns:

```r
column_des<-read.csv("C:/Users/rajsh/OneDrive/Documents/Rproject/Book1.csv")
print(column_des)
```

```
##                             Feature
## 1                               Age
## 2                           Anaemia
## 3               High blood pressure
## 4  Creatinine phosphokinase(CPK)
## 5                          Diabetes
## 6                 Ejection fraction
## 7                               Sex
## 8                         Platelets
## 9                   Serum creatinine
## 10                     Serum sodium
```

```
## 11                        Smoking
## 12                           Time
## 13            (target) death event
##                                                       Explanation      Measurement
## 1                                                 Age of the patient            Years
## 2                     Decrease of red blood cells or hemoglobin          Boolean
## 3                                  If a patient has hypertension          Boolean
## 4                          Level of the CPK enzyme in the blood            mcg/L
## 5                                    If the patient has diabetes          Boolean
## 6  Percentage of blood leaving the heart at each contraction       Percentage
## 7                                                     Woman or man           Binary
## 8                                         Platelets in the blood kiloplatelets/mL
## 9                                   Level of creatinine in the blood            mg/dL
## 10                                     Level of sodium in the blood            mEq/L
## 11                                          If the patient smokes          Boolean
## 12                                               Follow-up period             Days
## 13             If the patient died during the follow-up period          Boolean
##                  Range
## 1         [40,..., 95]
## 2                 0, 1
## 3                 0, 1
## 4       [23,..., 7861]
## 5                 0, 1
## 6         [14,..., 80]
## 7                 0, 1
## 8  [25.01,..., 850.00]
## 9     [0.50,..., 9.40]
## 10      [114,..., 148]
## 11                0, 1
## 12          [4,...,285]
## 13                0, 1
```

The hospital physician considered a patient having **anaemia** if haematocrit levels were lower than 36%. The **creatinine phosphokinase (CPK)** states the level of the CPK enzyme in blood. When a muscle tissue gets damaged, CPK flows into the blood. Therefore, high levels of CPK in the blood of a patient might indicate a heart failure or injury.It is measured in microgram per litre (mcg/L). The **ejection fraction** states the percentage of how much blood the left ventricle pumps out with each contraction. The **serum creatinine** is a waste product generated by creatine, when a muscle breaks down.Doctors focus on serum creatinine in blood to check kidney function. If a patient has high levels of serum creatinine, it may indicate renal dysfunction.A normal range for serum creatinine is approximately 0.6 to 1.3 milligrams per deciliter (mg/dL) for adult males and 0.5 to 1.2 mg/dL for adult females. The **serum sodium test** is a routine blood exam that indicates if a patient has normal levels of sodium in the blood. An abnormally low level of sodium(<125 mEq/L) in the blood might be caused by heart failure.mEq/L represents milliequivalents per liter. The **death event** feature, that we use as the target in our binary classification study, states if the patient died or survived before the end of the follow-up period, that was 130 days on average.

Purpose of my project:Carrying out EDA to look for important factors for predicting survival of patients from heart failure.

```r
#loading necessary libraries
library(ggplot2)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(moments)
```

```r
#Loading dataset
df<-read.csv("C:/Users/rajsh/OneDrive/Documents/Rproject/heart_failure_clinical_records_dataset.csv")
head(df)
```

```
##   age anaemia creatinine_phosphokinase diabetes ejection_fraction
## 1  75       0                      582        0                20
## 2  55       0                     7861        0                38
## 3  65       0                      146        0                20
## 4  50       1                      111        0                20
## 5  65       1                      160        1                20
## 6  90       1                       47        0                40
##   high_blood_pressure platelets serum_creatinine serum_sodium sex smoking time
## 1                   1   265.000              1.9          130   1       0    4
## 2                   0   263.358              1.1          136   1       0    6
## 3                   0   162.000              1.3          129   1       1    7
## 4                   0   210.000              1.9          137   1       0    7
## 5                   0   327.000              2.7          116   0       0    8
## 6                   1   204.000              2.1          132   1       1    8
##   DEATH_EVENT
## 1           1
## 2           1
## 3           1
## 4           1
## 5           1
## 6           1
```

```r
#Structure of data
cat("Shape of the dataset is:",dim(df),"\n")
```

```
## Shape of the dataset is: 299 13
```

```r
str(df)
```

```
## 'data.frame':    299 obs. of  13 variables:
##  $ age                     : num  75 55 65 50 65 90 75 60 65 80 ...
##  $ anaemia                 : int  0 0 0 1 1 1 1 1 0 1 ...
##  $ creatinine_phosphokinase: int  582 7861 146 111 160 47 246 315 157 123 ...
##  $ diabetes                : int  0 0 0 0 1 0 0 1 0 0 ...
```

```
##  $ ejection_fraction       : int  20 38 20 20 20 40 15 60 65 35 ...
##  $ high_blood_pressure     : int  1 0 0 0 0 1 0 0 0 1 ...
##  $ platelets               : num  265 263 162 210 327 ...
##  $ serum_creatinine        : num  1.9 1.1 1.3 1.9 2.7 2.1 1.2 1.1 1.5 9.4 ...
##  $ serum_sodium            : int  130 136 129 137 116 132 137 131 138 133 ...
##  $ sex                     : int  1 1 1 1 0 1 1 1 0 1 ...
##  $ smoking                 : int  0 0 1 0 0 1 0 1 0 1 ...
##  $ time                    : int  4 6 7 7 8 8 10 10 10 10 ...
##  $ DEATH_EVENT             : int  1 1 1 1 1 1 1 1 1 1 ...
```

Since age is measured in years and platelets are count so they are integer columns, thus converting them into integer. By description of dataset we know that anaemia,high blood pressure,diabetes,sex and smoking are categorical columns which are encoded with 0 and 1.

```r
df$age <- as.integer(df$age)
str(df)
```

```
## 'data.frame':    299 obs. of  13 variables:
##  $ age                     : int  75 55 65 50 65 90 75 60 65 80 ...
##  $ anaemia                 : int  0 0 0 1 1 1 1 1 0 1 ...
##  $ creatinine_phosphokinase: int  582 7861 146 111 160 47 246 315 157 123 ...
##  $ diabetes                : int  0 0 0 0 1 0 0 1 0 0 ...
##  $ ejection_fraction       : int  20 38 20 20 20 40 15 60 65 35 ...
##  $ high_blood_pressure     : int  1 0 0 0 0 1 0 0 0 1 ...
##  $ platelets               : num  265 263 162 210 327 ...
##  $ serum_creatinine        : num  1.9 1.1 1.3 1.9 2.7 2.1 1.2 1.1 1.5 9.4 ...
##  $ serum_sodium            : int  130 136 129 137 116 132 137 131 138 133 ...
##  $ sex                     : int  1 1 1 1 0 1 1 1 0 1 ...
##  $ smoking                 : int  0 0 1 0 0 1 0 1 0 1 ...
##  $ time                    : int  4 6 7 7 8 8 10 10 10 10 ...
##  $ DEATH_EVENT             : int  1 1 1 1 1 1 1 1 1 1 ...
```

```r
#Getting basic descriptive statistic summary of categorical columns
#For Anaemia
Anaemia_df <- data.frame(
  Anaemia = c("Present", "Absent"),
  Full_sampleNumber = c(sum(df$anaemia), 299 - sum(df$anaemia)),
  Full_samplePercentage = c(sum(df$anaemia) * 100 / nrow(df), (299 - sum(df$anaemia)) * 100 / nrow(df))
  Dead_patientsNumber = c(sum(df[df$DEATH_EVENT == 1, ]$anaemia),sum(df$DEATH_EVENT)-sum(df[df$DEATH_EVE
  Dead_patientsPercentage = c(sum(df[df$DEATH_EVENT == 1, ]$anaemia) * 100 /sum(df$DEATH_EVENT), (sum(d
  Survived_patientsNumber = c(sum(df[df$DEATH_EVENT == 0, ]$anaemia), ((299-sum(df$DEATH_EVENT)) - sum(
  Survived_patientsPercentage = c(sum(df[df$DEATH_EVENT == 0, ]$anaemia) * 100 /(299-sum(df$DEATH_EVENT
)
print(Anaemia_df)
```

```
##   Anaemia Full_sampleNumber Full_samplePercentage Dead_patientsNumber
## 1 Present               129              43.14381                  46
## 2  Absent               170              56.85619                  50
##   Dead_patientsPercentage Survived_patientsNumber Survived_patientsPercentage
## 1                47.91667                      83                     40.8867
## 2                52.08333                     120                     59.1133
```

```r
#For High blood pressure
High_blood_pressure_df <- data.frame(
  High_blood_pressure = c("Present", "Absent"),
  Full_sampleNumber = c(sum(df$high_blood_pressure), 299 - sum(df$high_blood_pressure)),
  Full_samplePercentage = c(sum(df$high_blood_pressure) * 100 / nrow(df), (299 - sum(df$high_blood_pres
  Dead_patientsNumber = c(sum(df[df$DEATH_EVENT == 1, ]$high_blood_pressure), sum(df$DEATH_EVENT) - sum
  Dead_patientsPercentage = c(sum(df[df$DEATH_EVENT == 1, ]$high_blood_pressure) * 100 / sum(df$DEATH_E
  Survived_patientsNumber = c(sum(df[df$DEATH_EVENT == 0, ]$high_blood_pressure), (299 - sum(df$DEATH_E
  Survived_patientsPercentage = c(sum(df[df$DEATH_EVENT == 0, ]$high_blood_pressure) * 100 / (299 - sum
)
print(High_blood_pressure_df)
```

```
##   High_blood_pressure Full_sampleNumber Full_samplePercentage
## 1             Present               105              35.11706
## 2              Absent               194              64.88294
##   Dead_patientsNumber Dead_patientsPercentage Survived_patientsNumber
## 1                  39                  40.625                      66
## 2                  57                  59.375                     137
##   Survived_patientsPercentage
## 1                    32.51232
## 2                    67.48768
```

```r
# For Diabetes
Diabetes_df <- data.frame(
  Diabetes = c("Present", "Absent"),
  Full_sampleNumber = c(sum(df$diabetes), 299 - sum(df$diabetes)),
  Full_samplePercentage = c(sum(df$diabetes) * 100 / nrow(df), (299 - sum(df$diabetes)) * 100 / nrow(df)
  Dead_patientsNumber = c(sum(df[df$DEATH_EVENT == 1, ]$diabetes), sum(df$DEATH_EVENT) - sum(df[df$DEAT
  Dead_patientsPercentage = c(sum(df[df$DEATH_EVENT == 1, ]$diabetes) * 100 / sum(df$DEATH_EVENT), (sum
  Survived_patientsNumber = c(sum(df[df$DEATH_EVENT == 0, ]$diabetes), ((299 - sum(df$DEATH_EVENT)) - su
  Survived_patientsPercentage = c(sum(df[df$DEATH_EVENT == 0, ]$diabetes) * 100 / (299 - sum(df$DEATH_E
)
print(Diabetes_df)
```

```
##   Diabetes Full_sampleNumber Full_samplePercentage Dead_patientsNumber
## 1  Present               125              41.80602                  40
## 2   Absent               174              58.19398                  56
##   Dead_patientsPercentage Survived_patientsNumber Survived_patientsPercentage
## 1                41.66667                      85                    41.87192
## 2                58.33333                     118                    58.12808
```

```r
# For Sex
Sex_df <- data.frame(
  Sex = c("Man", "Female"),
  Full_sampleNumber = c(sum(df$sex), 299 - sum(df$sex)),
  Full_samplePercentage = c(sum(df$sex) * 100 / nrow(df), (299 - sum(df$sex)) * 100 / nrow(df)),
  Dead_patientsNumber = c(sum(df[df$DEATH_EVENT == 1, ]$sex), sum(df$DEATH_EVENT) - sum(df[df$DEATH_EVE
  Dead_patientsPercentage = c(sum(df[df$DEATH_EVENT == 1, ]$sex) * 100 / sum(df$DEATH_EVENT), (sum(df$DE
  Survived_patientsNumber = c(sum(df[df$DEATH_EVENT == 0, ]$sex), ((299 - sum(df$DEATH_EVENT)) - sum(df
  Survived_patientsPercentage = c(sum(df[df$DEATH_EVENT == 0, ]$sex) * 100 / (299 - sum(df$DEATH_EVENT)
)
print(Sex_df)
```

```
##      Sex Full_sampleNumber Full_samplePercentage Dead_patientsNumber
## 1    Man               194              64.88294                  62
## 2 Female               105              35.11706                  34
##   Dead_patientsPercentage Survived_patientsNumber Survived_patientsPercentage
## 1                64.58333                     132                    65.02463
## 2                35.41667                      71                    34.97537
```

```
# For Smoking
Smoking_df <- data.frame(
  Smoking = c("Present", "Absent"),
  Full_sampleNumber = c(sum(df$smoking), 299 - sum(df$smoking)),
  Full_samplePercentage = c(sum(df$smoking) * 100 / nrow(df), (299 - sum(df$smoking)) * 100 / nrow(df))
  Dead_patientsNumber = c(sum(df[df$DEATH_EVENT == 1, ]$smoking), sum(df$DEATH_EVENT) - sum(df[df$DEATH_
  Dead_patientsPercentage = c(sum(df[df$DEATH_EVENT == 1, ]$smoking) * 100 / sum(df$DEATH_EVENT), (sum(d
  Survived_patientsNumber = c(sum(df[df$DEATH_EVENT == 0, ]$smoking), ((299 - sum(df$DEATH_EVENT)) - sum
  Survived_patientsPercentage = c(sum(df[df$DEATH_EVENT == 0, ]$smoking) * 100 / (299 - sum(df$DEATH_EVE
)
print(Smoking_df)
```

```
##   Smoking Full_sampleNumber Full_samplePercentage Dead_patientsNumber
## 1 Present                96              32.10702                  30
## 2  Absent               203              67.89298                  66
##   Dead_patientsPercentage Survived_patientsNumber Survived_patientsPercentage
## 1                   31.25                      66                    32.51232
## 2                   68.75                     137                    67.48768
```

We can clearly observe that: 1) Out of 299 patients 129 were found to have anaemia which is about 43% of total population. Only 64.34% patient who had anaemia could survive till follow-up period. 2) Out of 299 patients 105 were found to have high blood pressure which is about 35% of total population. Only 62.85% patient who had high blood pressure could survive till follow-up period. 3) Out of 299 patients 125 were found to have diabetes which is about 42% of total population. Only 68% patient who had diabetes could survive till follow-up period. 4) Male constituted 64.88% and Female constituted 35.12% of total population. 5) Out of 299 patients 96 were found to have diabetes which is about 32% of total population. Only 68.75% patient who had diabetes could survive till follow-up period.

Univariate analysis

```
#Getting basic descriptive statistic summary of age column
cat("For age","\n")
```

```
## For age
```

```
summary(df$age)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   40.00   51.00   60.00   60.83   70.00   95.00
```

```
cat("Standard deviation:",sd(df$age),"\n")
```

```
## Standard deviation: 11.895
```

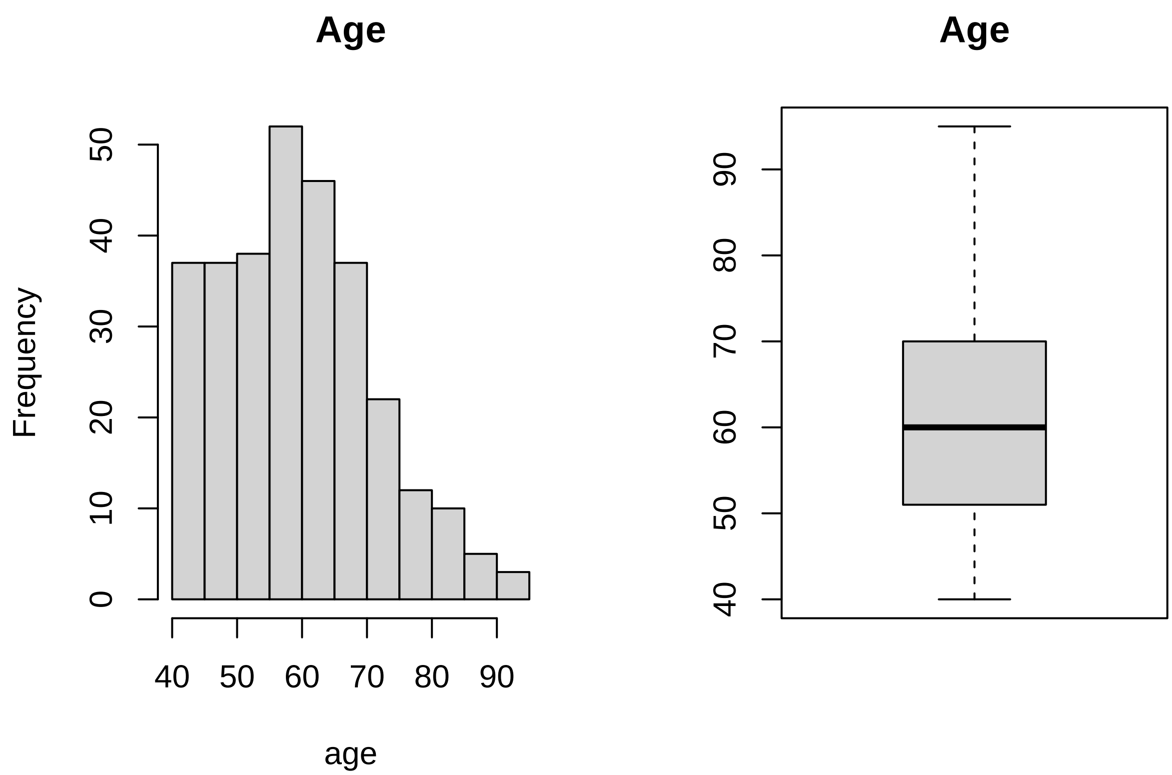
```r
cat("Skewness:",skewness(df$age),"\n")
```

```
## Skewness: 0.4220415
```

```r
cat("Kurtosis:",kurtosis(df$age),"\n","\n")
```

```
## Kurtosis: 2.798664
##
```

```r
#For age
par(mfrow=c(1,2))
hist(df$age,main="Age",xlab="age")
boxplot(df$age,main="Age")
```




```r
par(mfrow=c(1,1))
```

Age of patients lie between range 40-95 years with average age of 60.83 years and standard deviation of 11.895. Most of the patients have age 55-65 years.

```r
#Getting basic descriptive statistic summary of Creatinine phosphokinase
cat("For creatinine_phosphokinase","\n")
```

```
## For creatinine_phosphokinase
```

```r
summary(df$creatinine_phosphokinase)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    23.0   116.5   250.0   581.8   582.0  7861.0
```

```r
cat("Standard deviation:",sd(df$creatinine_phosphokinase),"\n")
```

```
## Standard deviation: 970.2879
```

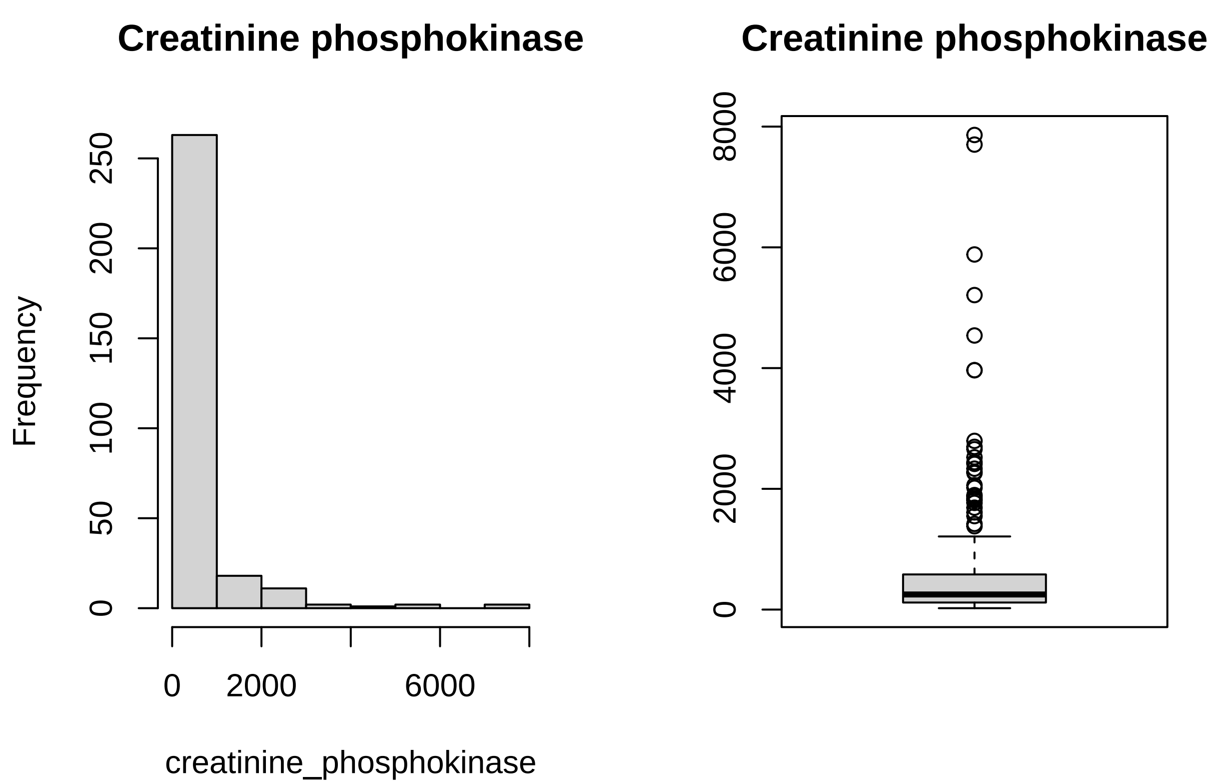
```r
cat("Skewness:",skewness(df$creatinine_phosphokinase),"\n")
```

```
## Skewness: 4.440689
```

```r
cat("Kurtosis:",kurtosis(df$creatinine_phosphokinase),"\n","\n")
```

```
## Kurtosis: 27.71046
##
```

```r
#For Creatinine phosphokinase
par(mfrow=c(1,2))
hist(df$creatinine_phosphokinase,main="Creatinine phosphokinase",xlab="creatinine_phosphokinase")
boxplot(df$creatinine_phosphokinase,main="Creatinine phosphokinase")
```



```r
par(mfrow=c(1,1))
```

Creatinine phosphokinase column is highly right skewed & peaked with range of 23-7861,standard deviation of 970.28, Skewness of 4.44 ,kurtosis of 27.7. From the box-plot we can see that it has many outliers.

```r
#Getting basic descriptive statistic summary of Ejection fraction
cat("For ejection_fraction","\n")
```

```
## For ejection_fraction
```

```r
summary(df$ejection_fraction)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   14.00   30.00   38.00   38.08   45.00   80.00
```

```r
cat("Standard deviation:",sd(df$ejection_fraction),"\n")
```

```
## Standard deviation: 11.83484
```

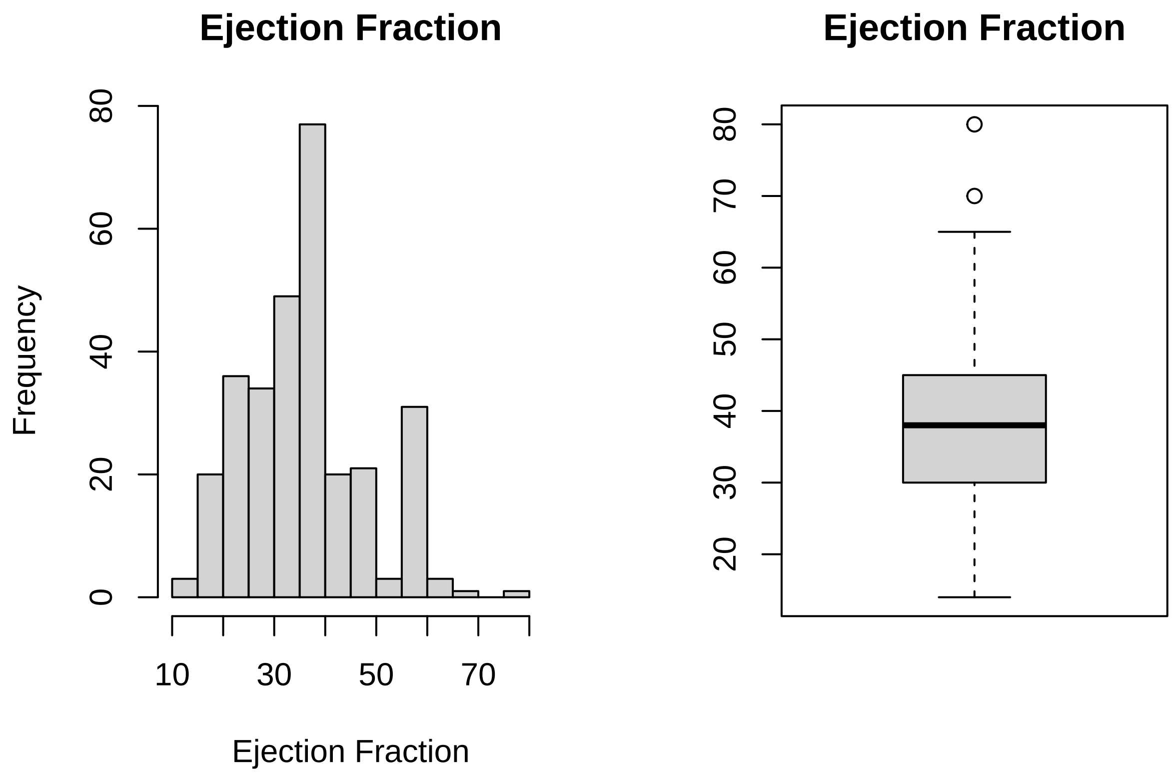
```r
cat("Skewness:",skewness(df$ejection_fraction),"\n")
```

```
## Skewness: 0.5525927
```

```r
cat("Kurtosis:",kurtosis(df$ejection_fraction),"\n","\n")
```

```
## Kurtosis: 3.02072
##
```

```r
#For Ejection fraction
par(mfrow=c(1,2))
hist(df$ejection_fraction, main="Ejection Fraction", xlab="Ejection Fraction")
boxplot(df$ejection_fraction, main="Ejection Fraction")
```




```r
par(mfrow=c(1,1))
```

Ejection fraction column has range of 14-80 ,mean of 38.08 ,standard deviation of 11.83, Skewness of 0.55 ,kurtosis of 3.02.

```r
#Getting basic descriptive statistic summary of Platelets
cat("For plateles","\n")
```

```
## For plateles
```

```r
summary(df$platelets)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
##    25.1   211.5   262.0   262.7   303.5   850.0
```

```r
cat("Standard deviation:",sd(df$platelets),"\n")
```

```
## Standard deviation: 98.39959
```

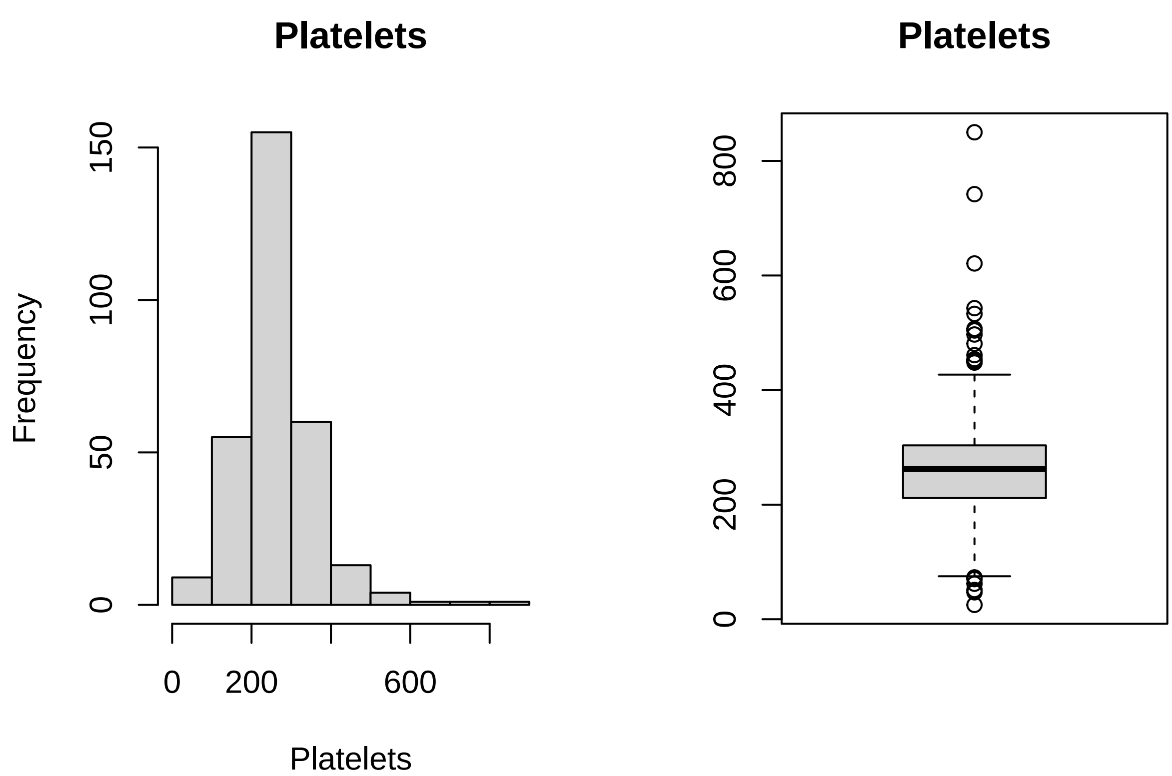
```r
cat("Skewness:",skewness(df$platelets),"\n")
```

```
## Skewness: 1.425942
```

```r
cat("Kurtosis:",kurtosis(df$platelets),"\n","\n")
```

```
## Kurtosis: 8.950815
##
```

```r
#For Platelets
par(mfrow=c(1,2))
hist(df$platelets, main="Platelets", xlab="Platelets")
boxplot(df$platelets, main="Platelets")
```




```r
par(mfrow=c(1,1))
```

Platelets column is high peaked column with range of 25100-850000,mean of 263358 ,standard deviation of 97804.24, Skewness of 1.45 ,kurtosis of 9.08. From the box-plot we can see that it has many outliers.

```r
#Getting basic descriptive statistic summary of Serum creatinine
cat("For serum_creatinine","\n")
```

```
## For serum_creatinine
```

```r
summary(df$serum_creatinine)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   0.500   0.900   1.100   1.394   1.400   9.400
```

```r
cat("Standard deviation:",sd(df$serum_creatinine),"\n")
```

```
## Standard deviation: 1.03451
```

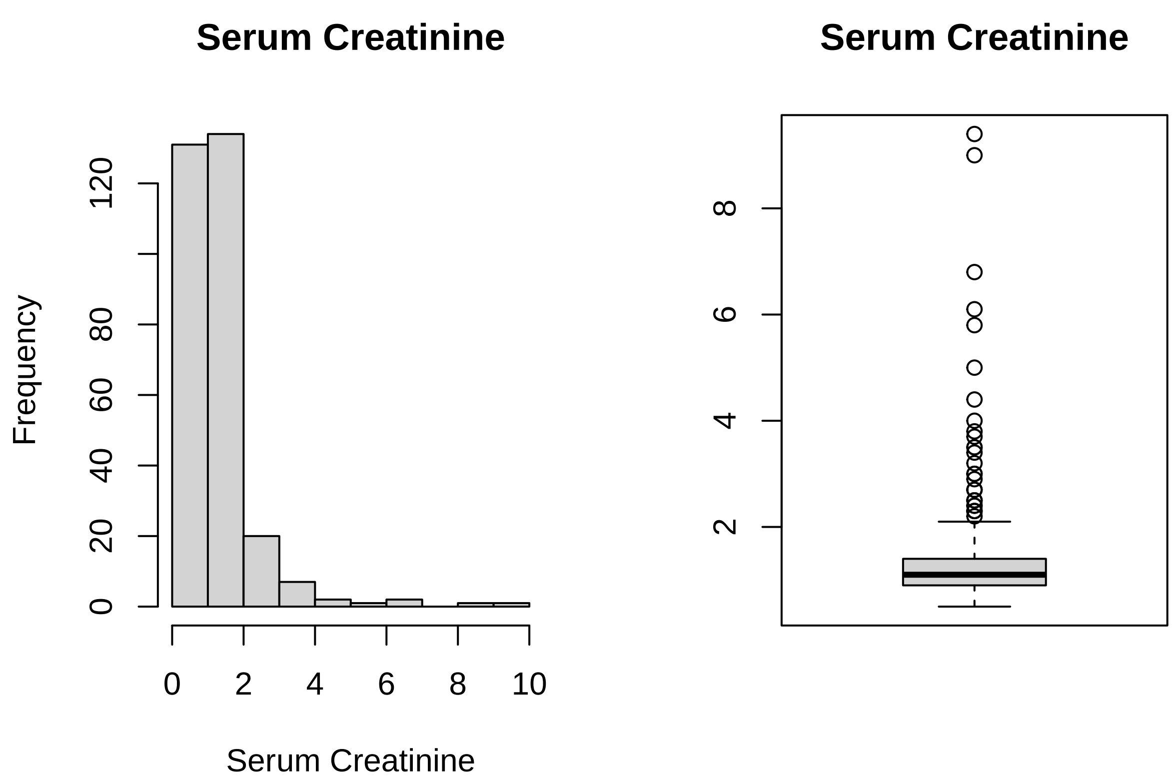
```r
cat("Skewness:",skewness(df$serum_creatinine),"\n")
```

```
## Skewness: 4.43361
```

```r
cat("Kurtosis:",kurtosis(df$serum_creatinine),"\n","\n")
```

```
## Kurtosis: 28.37835
##
```

```r
#For Serum creatinine
par(mfrow=c(1,2))
hist(df$serum_creatinine, main="Serum Creatinine", xlab="Serum Creatinine")
boxplot(df$serum_creatinine, main="Serum Creatinine")
```




```r
par(mfrow=c(1,1))
```

Serum creatinine is highly right skewed & peaked with range of 0.5-9.4, standard deviation of 1.03,Skewness of 4.43 ,kurtosis of 28.37. From the box-plot we can see that it has many outliers.

```r
#Getting basic descriptive statistic summary of Serum sodium
cat("For serum_sodium","\n")
```

```
## For serum_sodium
```

```r
summary(df$serum_sodium)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   113.0   134.0   137.0   136.6   140.0   148.0
```

```r
cat("Standard deviation:",sd(df$serum_sodium),"\n")
```

```
## Standard deviation: 4.412477
```

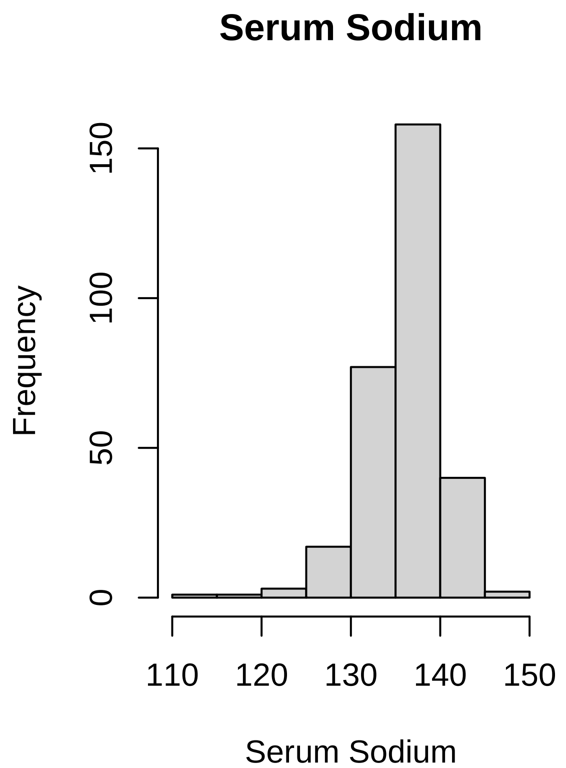
```r
cat("Skewness:",skewness(df$serum_sodium),"\n")
```

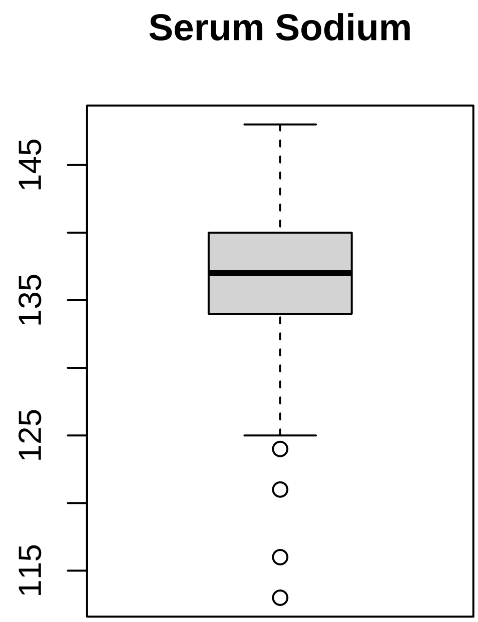
```
## Skewness: -1.04287
```

```r
cat("Kurtosis:",kurtosis(df$serum_sodium),"\n","\n")
```

```
## Kurtosis: 7.031142
##
```

```r
#For Serum sodium
par(mfrow=c(1,2))
hist(df$serum_sodium, main="Serum Sodium", xlab="Serum Sodium")
boxplot(df$serum_sodium, main="Serum Sodium")
```






```
par(mfrow=c(1,1))
```

Serum sodium has range of 113-148, mean of 136.6, standard deviation of 4.41,Skewness of -1.04,kurtosis of 7.03. It is left skewed.

```
#Getting basic descriptive statistic summary of Death event
cat("For time","\n")
```

```
## For time
```

```
summary(df$time)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##     4.0    73.0   115.0   130.3   203.0   285.0
```

```
cat("Standard deviation:",sd(df$time),"\n")
```

```
## Standard deviation: 77.61421
```

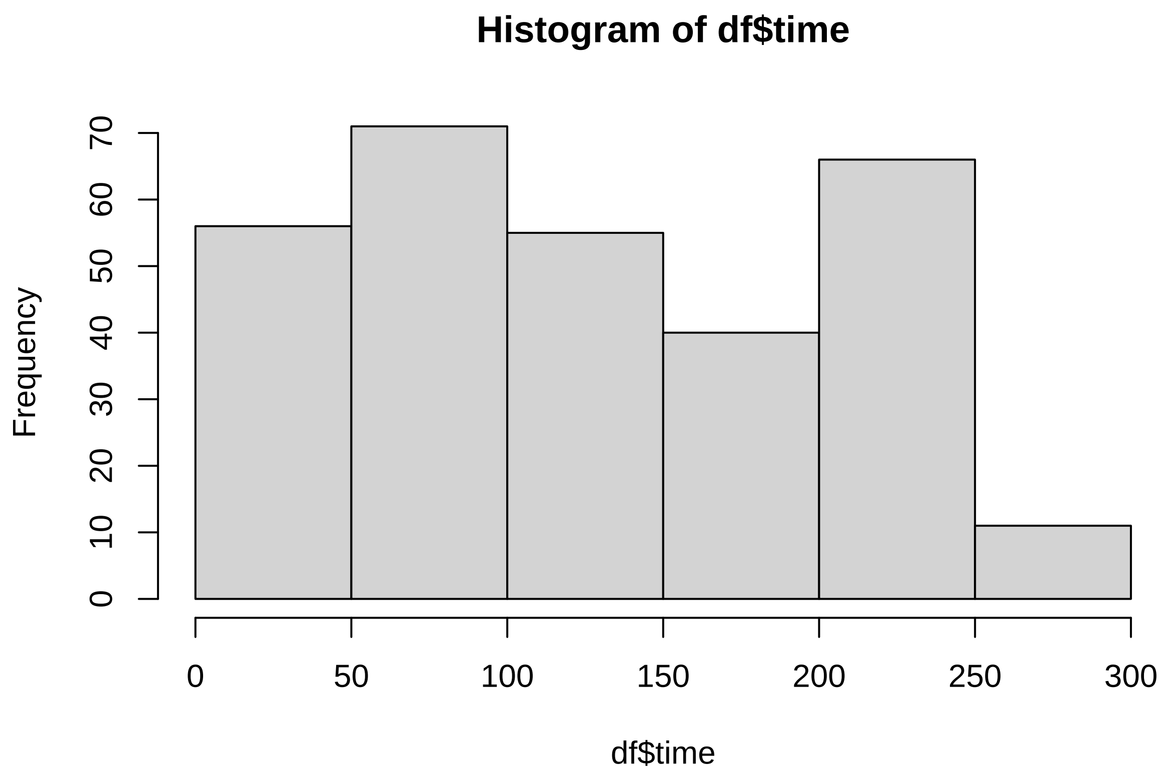
```
cat("Skewness:",skewness(df$time),"\n")
```

```
## Skewness: 0.1271606
```

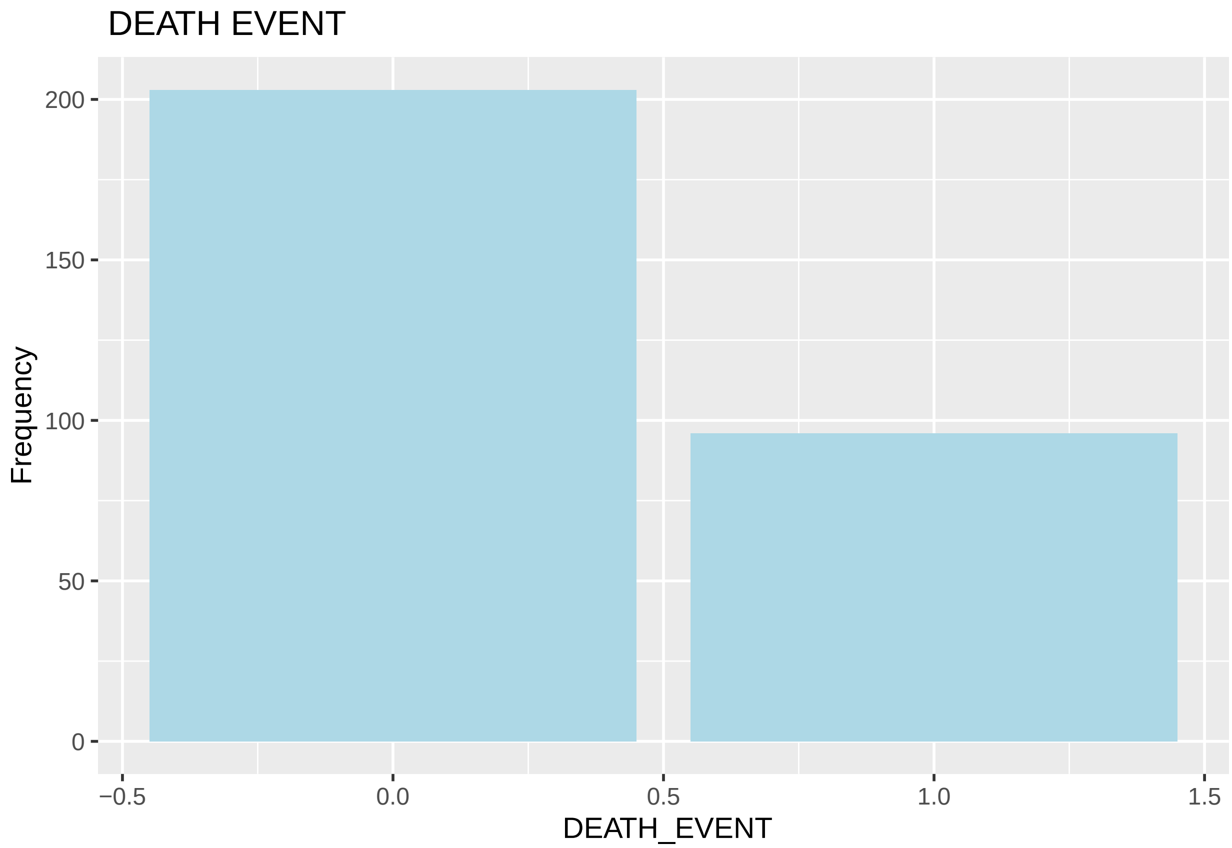
```
cat("Kurtosis:",kurtosis(df$time),"\n")
```

```
## Kurtosis: 1.788126
```

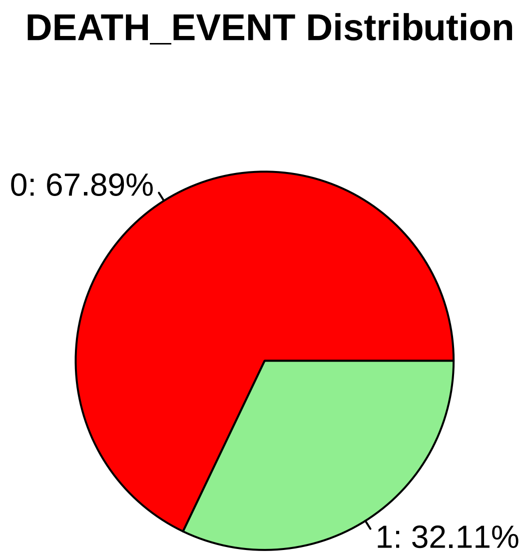
```
hist(df$time)
```




```
#For Death event
ggplot(df, aes(x =  DEATH_EVENT)) +geom_bar(fill = "lightblue") +labs(title = " DEATH EVENT", x = " DEA
```



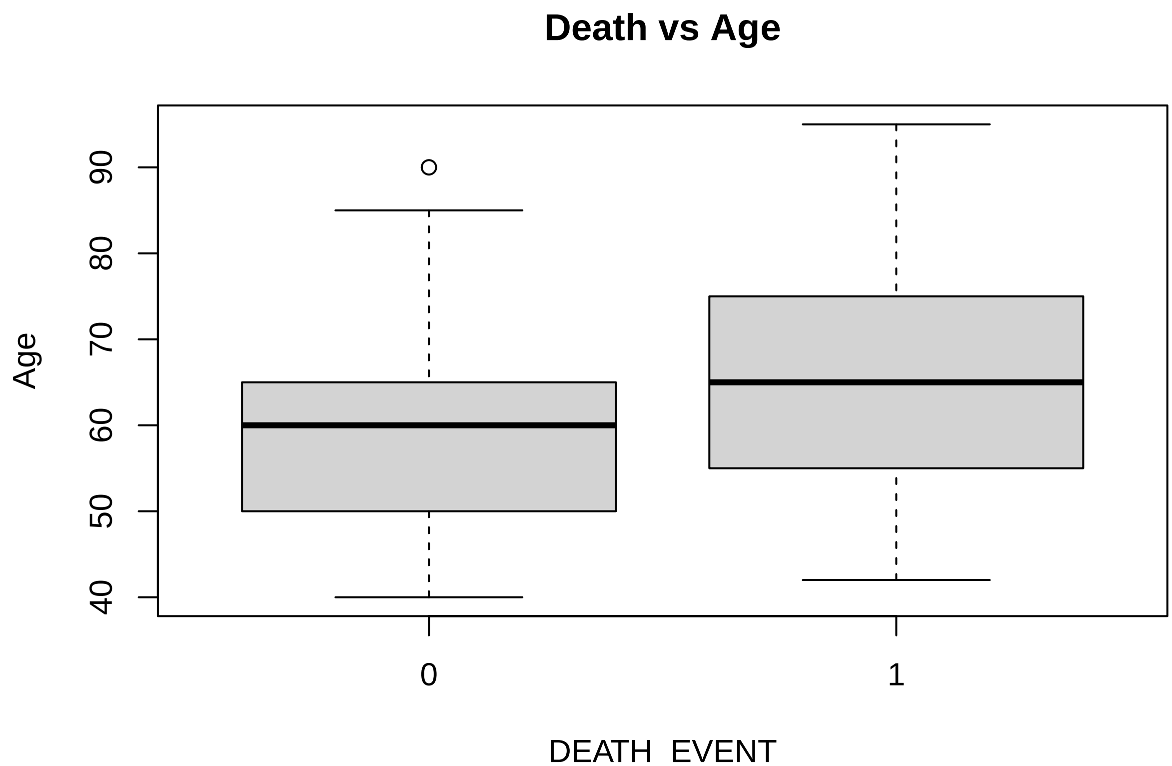

```
pie(table(df$ DEATH_EVENT), labels = paste0(names(table(df$ DEATH_EVENT)), ": ", round(table(df$ DEATH_E
```



Among 299 patients 67.89% died before follow-up period.

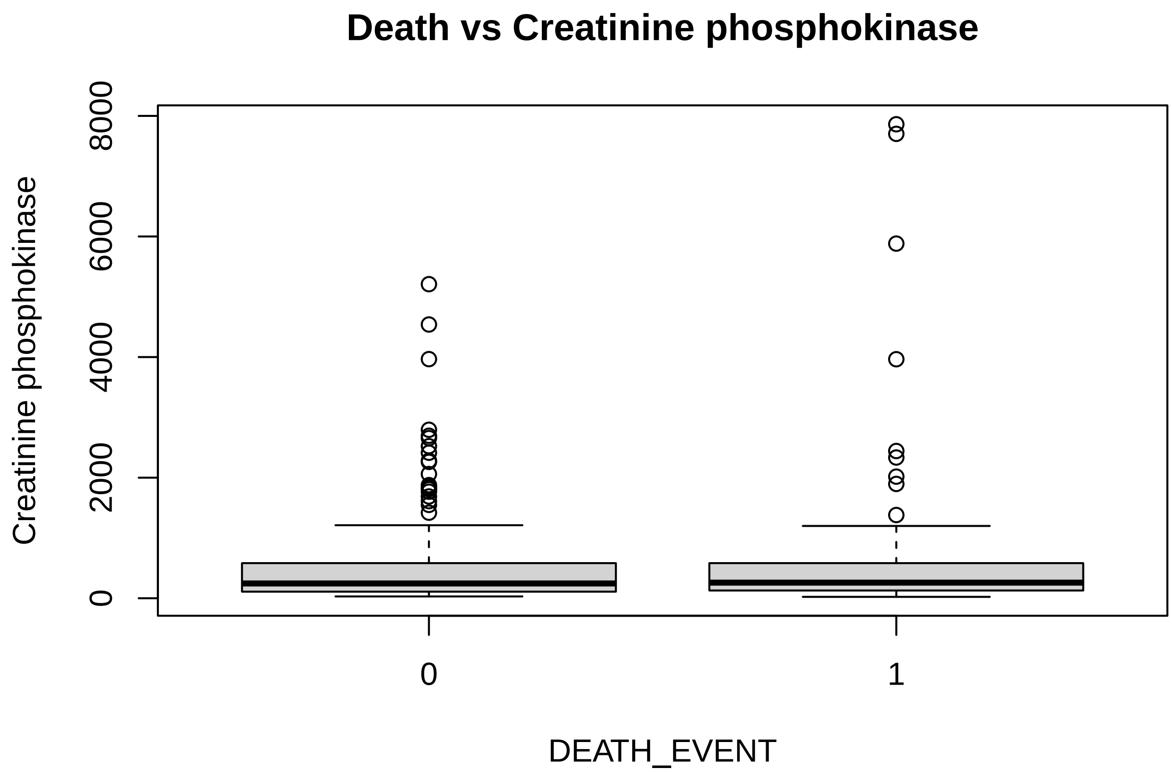
Bivariate analysis

```
#Death vs Age
boxplot(df$age ~ df$DEATH_EVENT, main = "Death vs Age", xlab = "DEATH_EVENT", ylab = "Age")
```

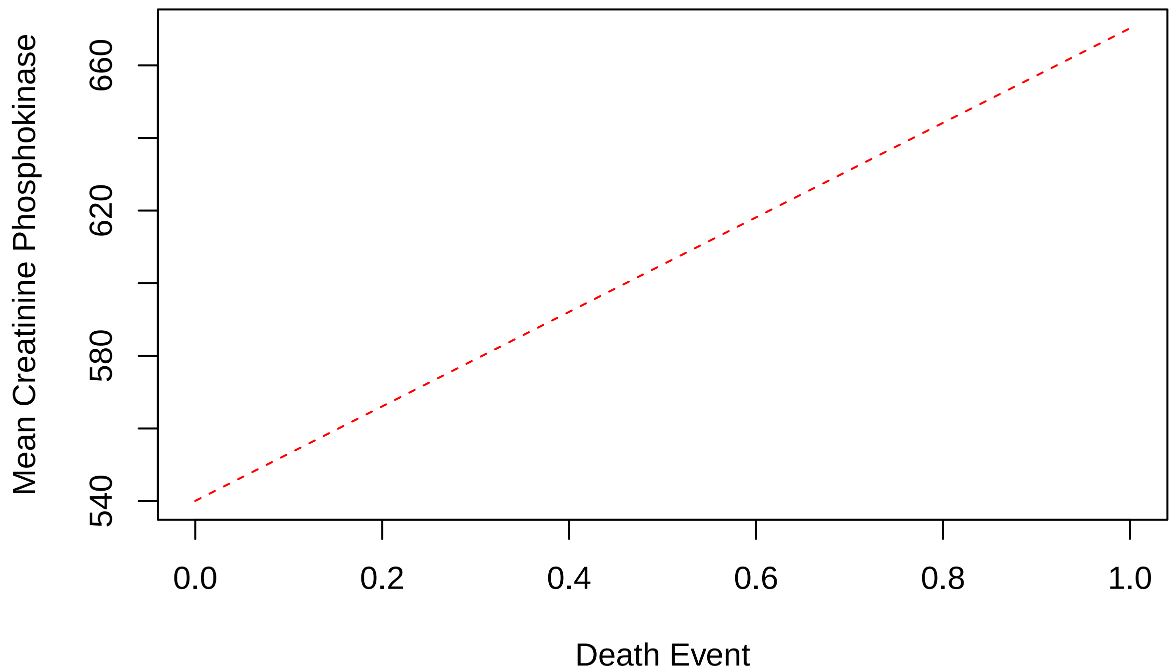


From death vs age plot we see that young age group people have more chances of survival.

```
#Death vs Creatinine phosphokinase
boxplot(df$creatinine_phosphokinase ~ df$DEATH_EVENT, main = "Death vs Creatinine phosphokinase", xlab =
```

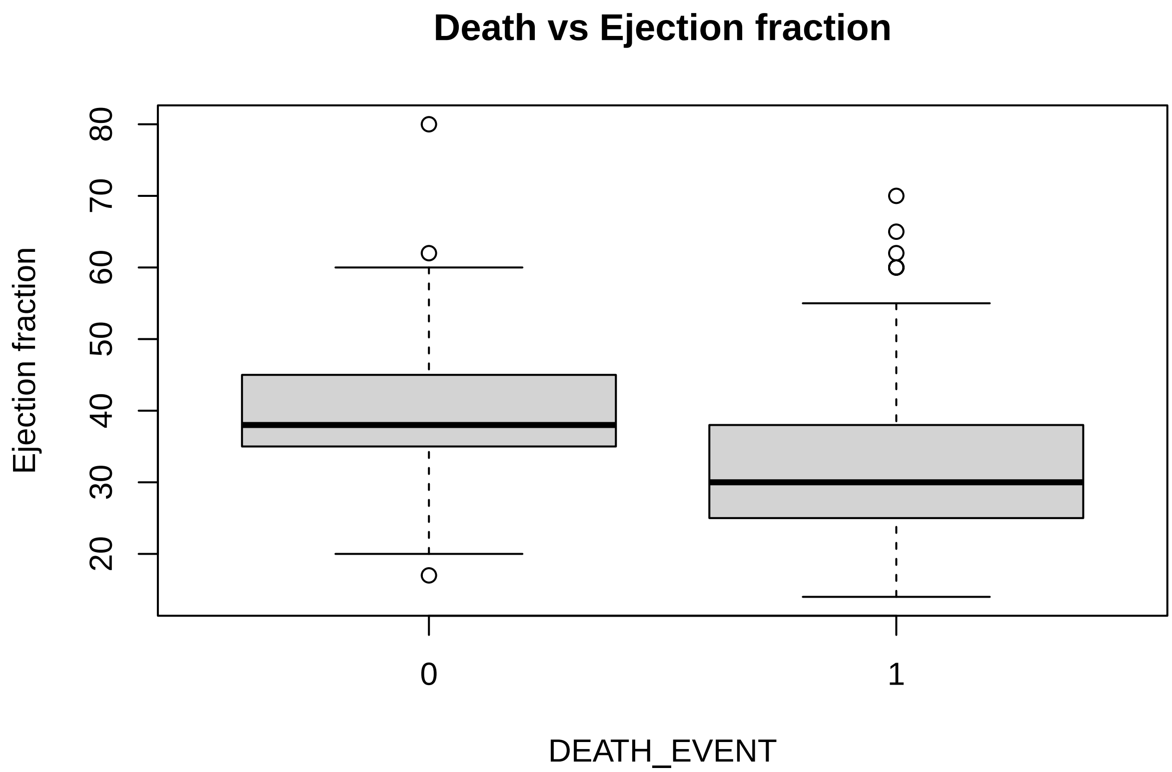



```
df_summary <- df %>%
  group_by(DEATH_EVENT) %>%
  summarize(mean_cpk = mean(creatinine_phosphokinase))

# Draw a line plot with the summary data
plot(df_summary$DEATH_EVENT, df_summary$mean_cpk, type = "l",
     xlab = "Death Event", ylab = "Mean Creatinine Phosphokinase",col="red",lty=2)
```



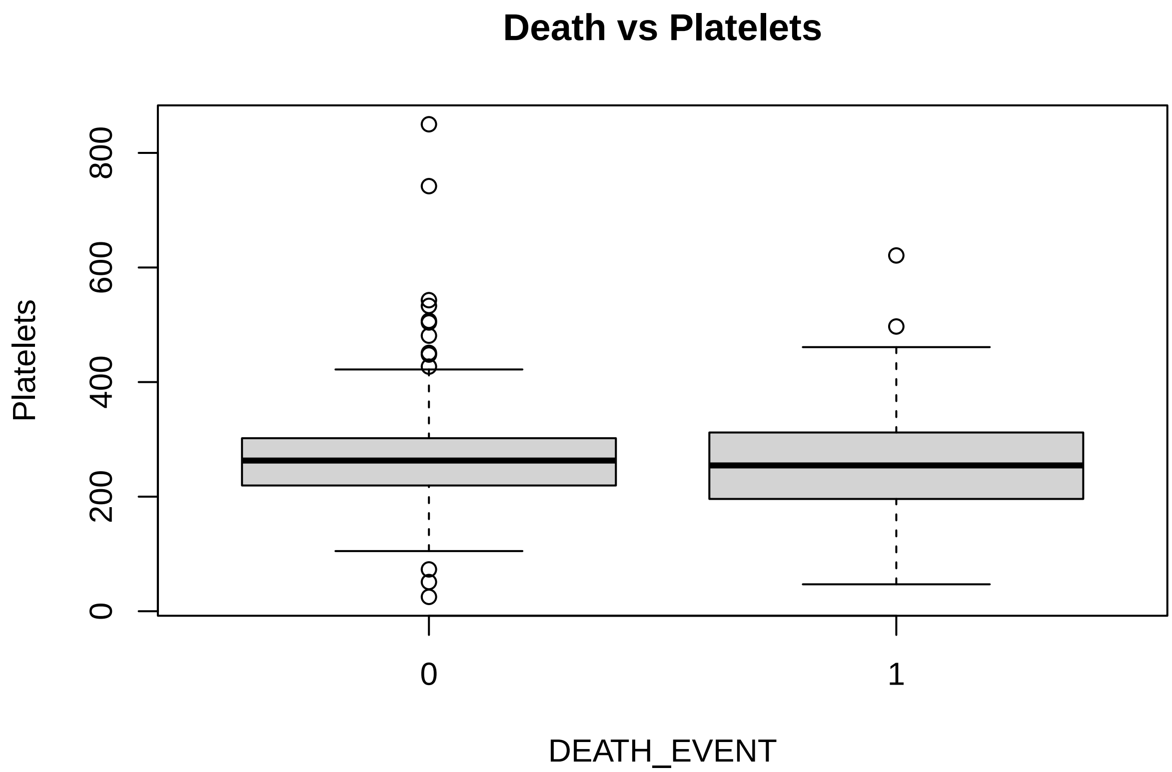
From the line plot we can see that on an average the patients who died had high value of CPK.We might consider it as potential factor to predict survival of patients.But since the range of CPK was too high than its mean so we cannot say with high certainty that it is a good factor to predict survival.

```
#Death vs Ejection fraction
boxplot(df$ejection_fraction ~ df$DEATH_EVENT, main = "Death vs Ejection fraction", xlab = "DEATH_EVENT
```

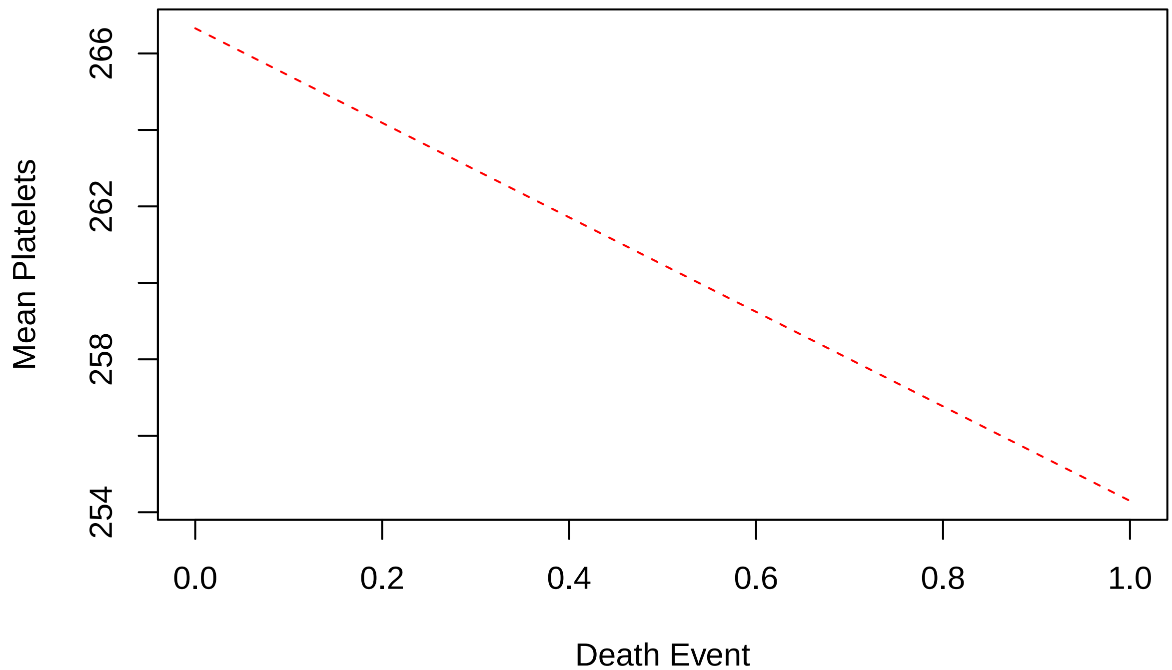


Ejection fraction vs death plot reveals that the people who died had low value of ejection fraction i.e. left ventricle does not pumps effectively with each contraction.

```
#Death vs Platelets
boxplot(df$platelets ~ df$DEATH_EVENT, main = "Death vs Platelets", xlab = "DEATH_EVENT", ylab = "Platel
```




```
df_summary <- df %>%
  group_by(DEATH_EVENT) %>%
  summarize(mean_plat = mean(platelets))

# Draw a line plot with the summary data
plot(df_summary$DEATH_EVENT, df_summary$mean_plat, type = "l",
     xlab = "Death Event", ylab = "Mean Platelets",col="red",lty=2)
```

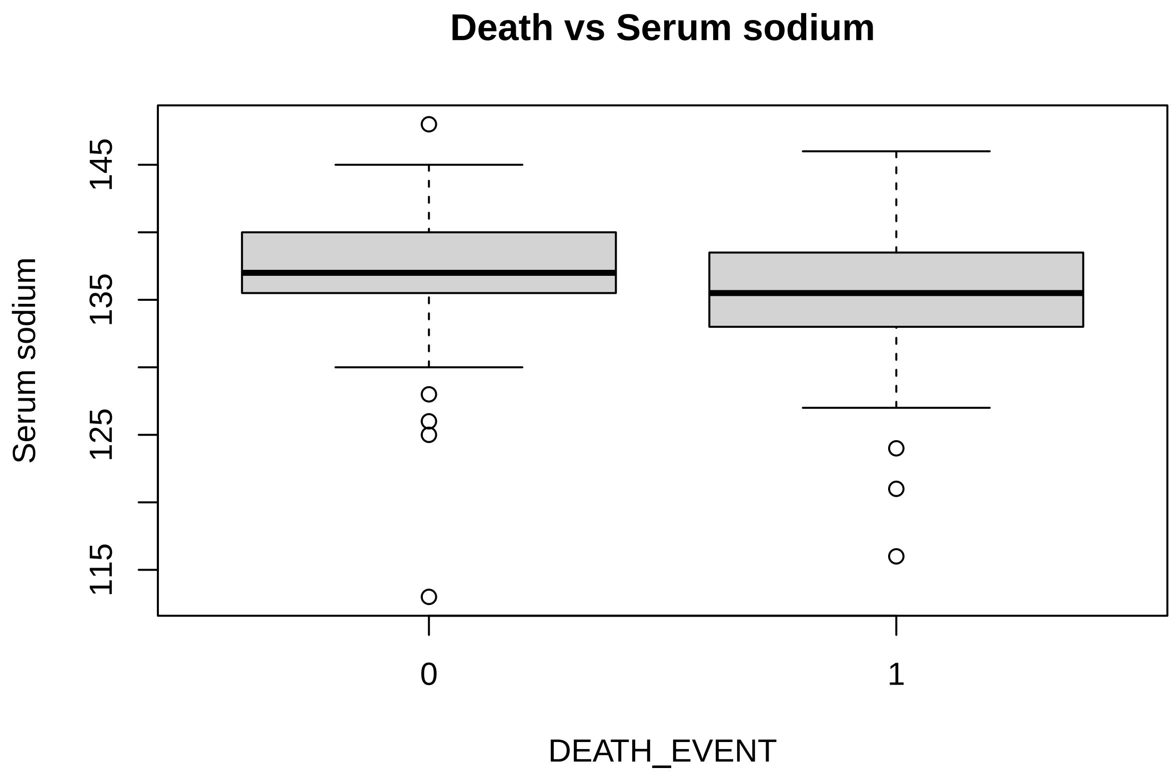


On Average plateletes count remained same for patients who survived and who died. Since there is very slight cange in average of platelets count.

```
#Death vs Serum creatinine
boxplot(df$serum_creatinine ~ df$DEATH_EVENT, main = "Death vs Serum creatinine", xlab = "DEATH_EVENT",
```

High value for Serum creatinine was observed for patients who died telling that it can be potential factor for predicting survival of patients.

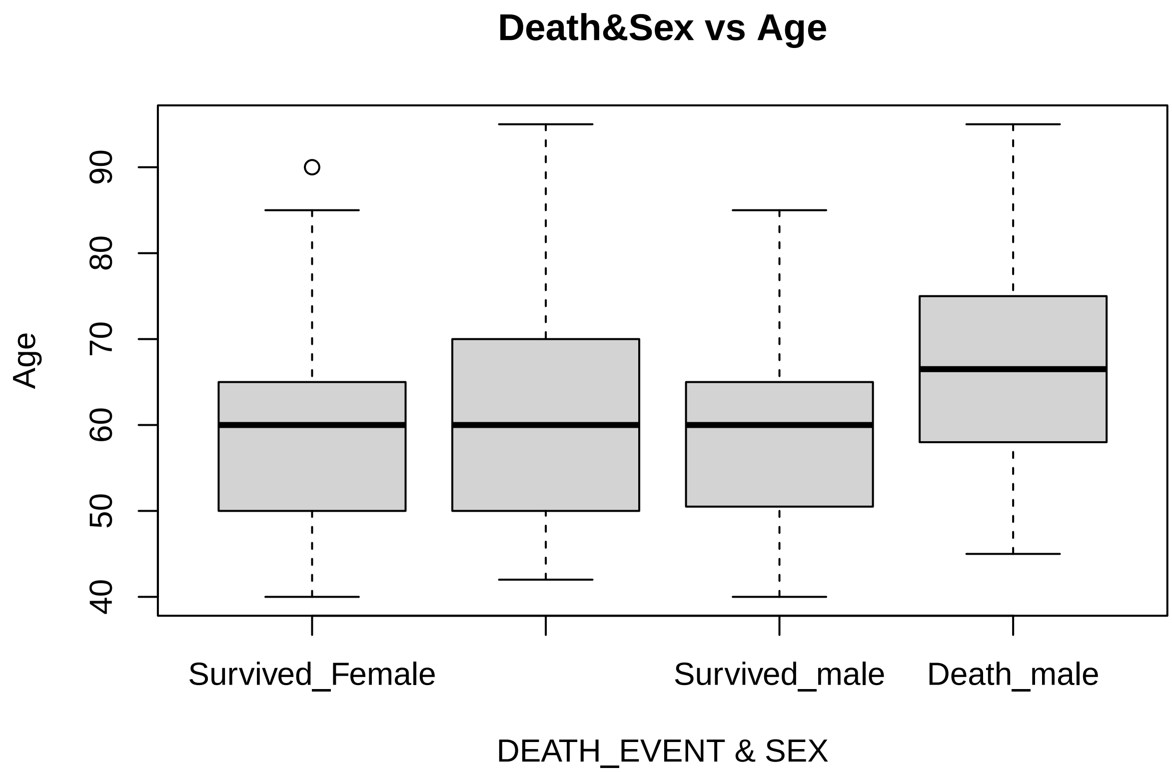
```
#Death vs Serum sodium
boxplot(df$serum_sodium ~ df$DEATH_EVENT, main = "Death vs Serum sodium", xlab = "DEATH_EVENT", ylab =
```



Low value for Serum sodium was observed for patients who died telling that it can be potential factor for predicting survival of patients.

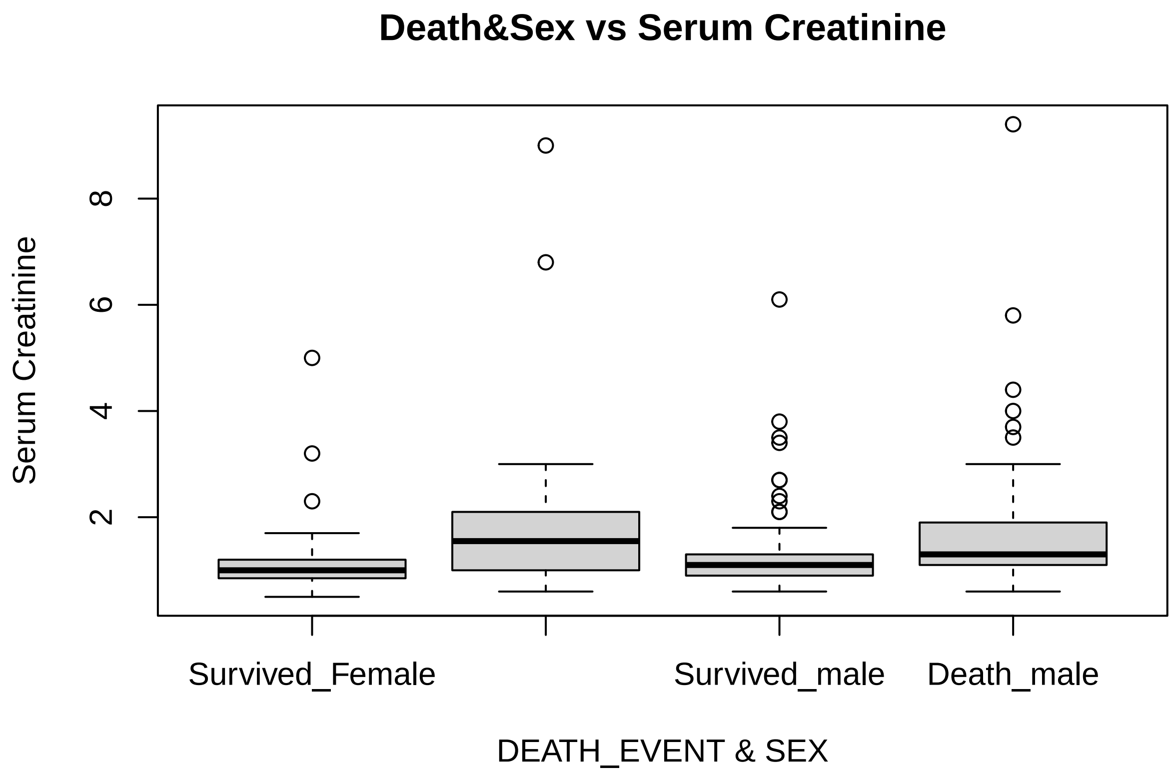
#Analysis of survival and sex of patients taken together

```
#Death&Sex vs Age
boxplot(df$age ~ interaction(df$DEATH_EVENT,df$sex), main = "Death&Sex vs Age", xlab = "DEATH_EVENT & SE
```



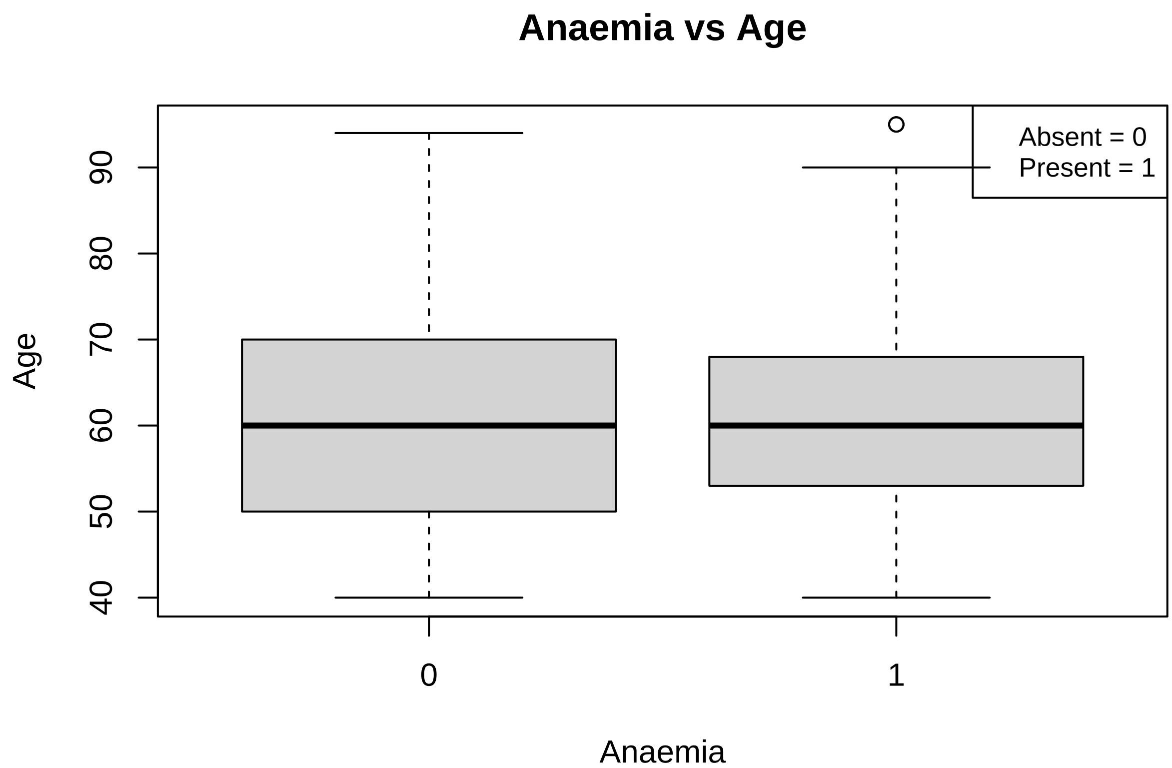
Among all patients male patients who were younger had high chances of survival since among those males who died older ones were majority.And same is observed for females.

```
#Death&Sex vs Serum Creatinine
boxplot(df$serum_creatinine ~ interaction(df$DEATH_EVENT,df$sex), main = "Death&Sex vs Serum Creatinine
```



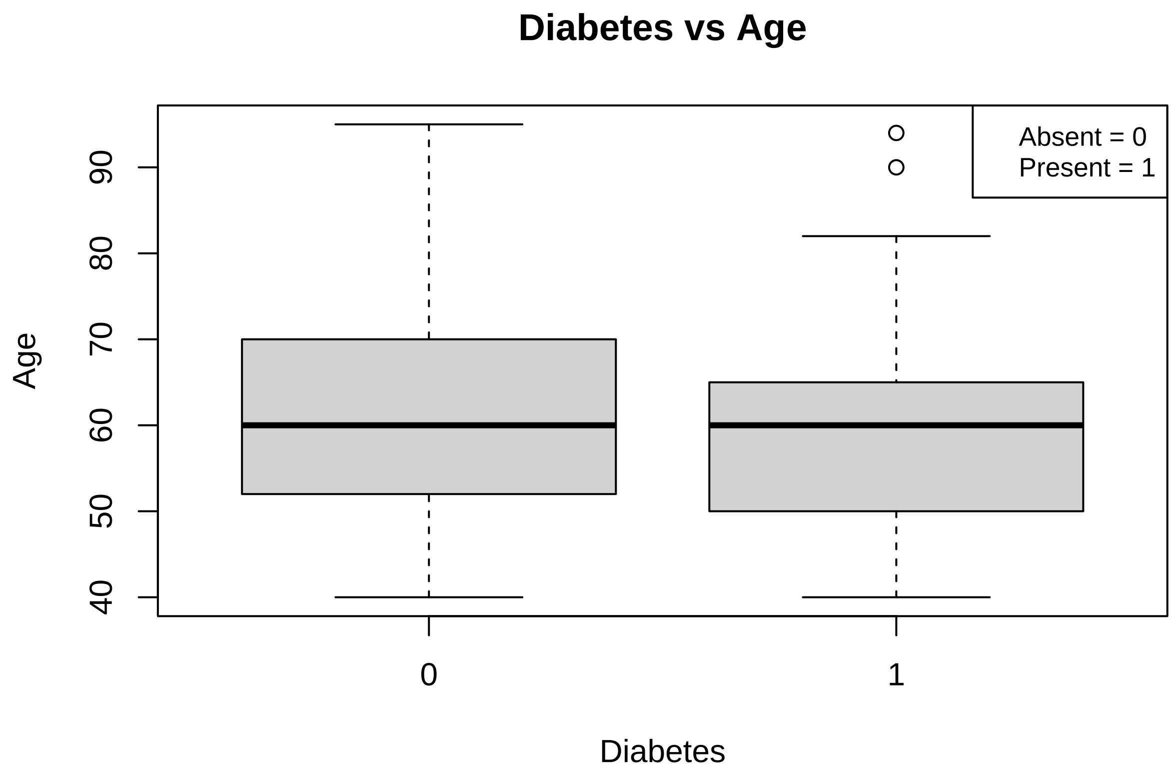
In both males and females the patients who had high level of Serum Creatinine died before follow up period. #Relationship between different feature columns

```r
#Anaemia vs Age
boxplot(df$age ~ df$anaemia, main = "Anaemia vs Age", xlab = "Anaemia", ylab = "Age")
legend("topright", legend = c("Absent = 0", "Present = 1"),cex=0.8)
```



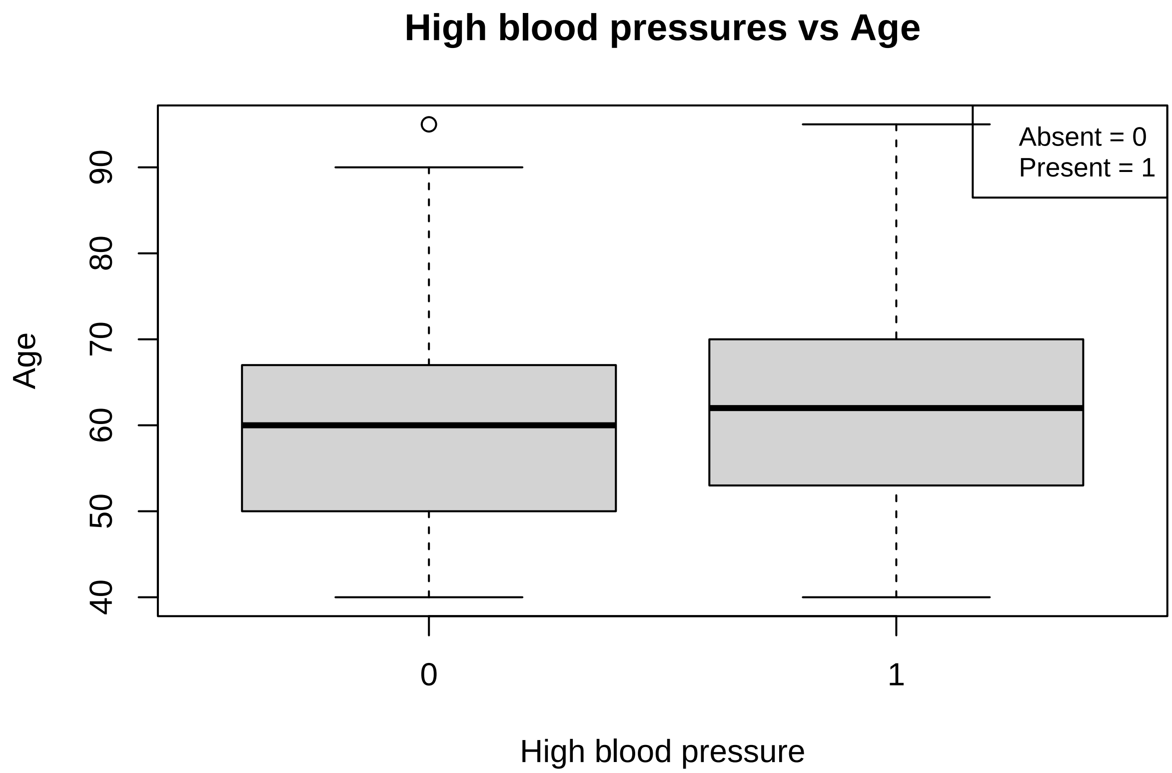
On average age remained same for patients who had anaemia and who didn't have anaemia.

```r
#Diabetes vs Age
boxplot(df$age ~ df$diabetes, main = "Diabetes vs Age", xlab = "Diabetes", ylab = "Age")
legend("topright", legend = c("Absent = 0", "Present = 1"),cex=0.8)
```



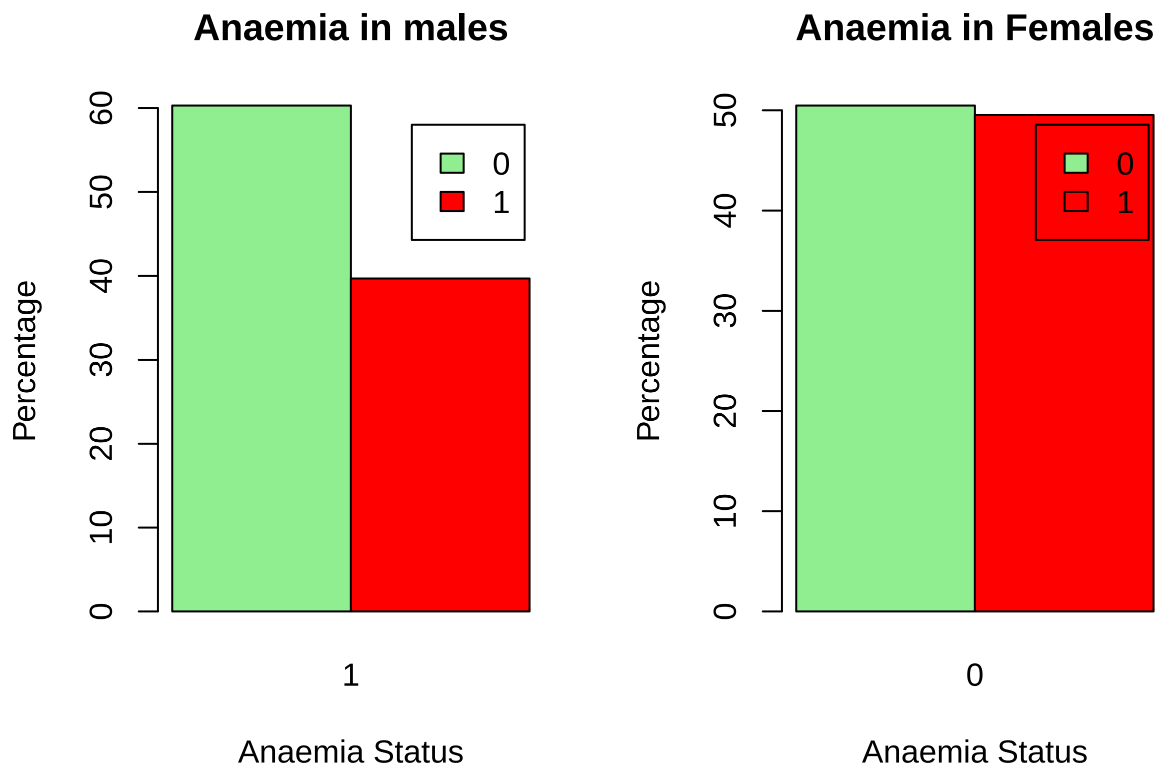
On average age remained same for patients who had diabetes and who didn't have diabetes.

```
#High blood pressure vs Age
boxplot(df$age ~ df$high_blood_pressure, main = "High blood pressures vs Age", xlab = "High blood pressu
legend("topright", legend = c("Absent = 0", "Present = 1"),cex=0.8)
```



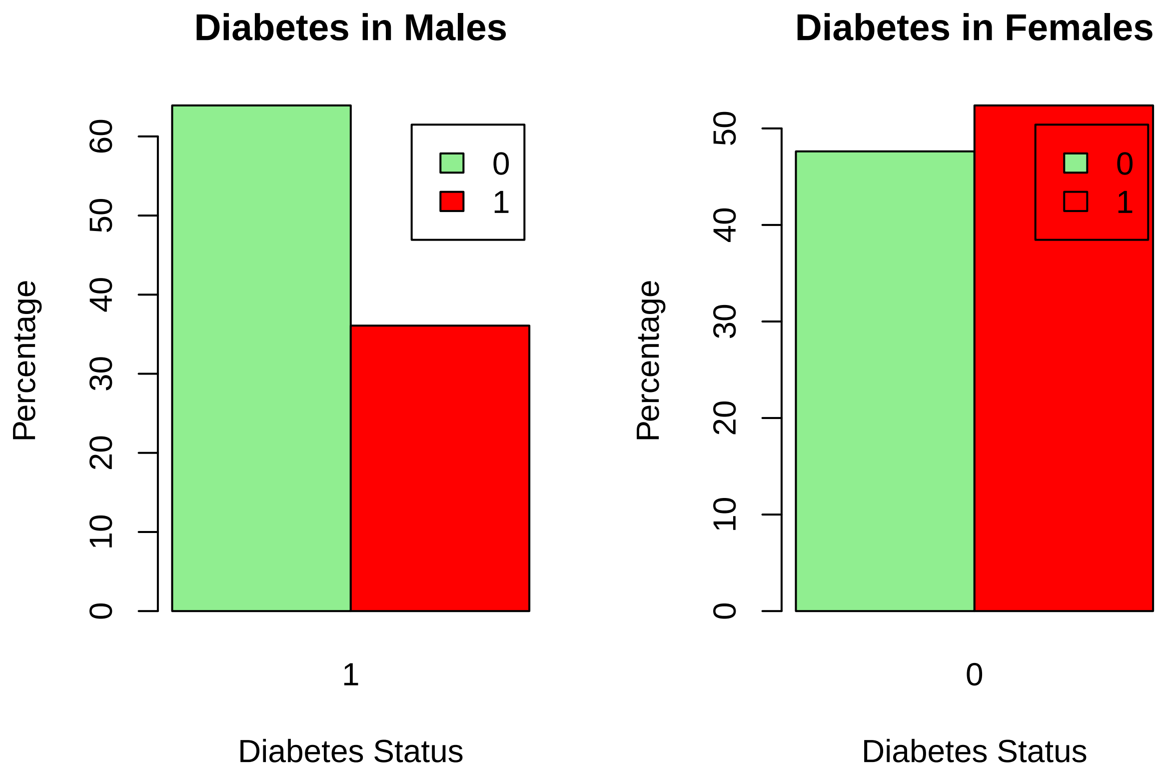
Patients who had high blood pressure were slightly aged than those who didn't had high blood pressure.

```r
#Anaemia & Sex
df_males <- subset(df, sex == 1)
df_females <- subset(df, sex == 0)

# Create a table for anaemia and sex
x <- table(df_males$anaemia, df_males$sex)
y <- table(df_females$anaemia, df_females$sex)
x_percentage <- prop.table(x, margin = 2) * 100
y_percentage <- prop.table(y, margin = 2) * 100  # Calculate percentages across columns (sex)

par(mfrow=c(1,2))
# Barplot for males with percentages
barplot(x_percentage, beside = TRUE, col = c("lightgreen", "red"),
        legend = rownames(y_percentage), main = "Anaemia in males",
        xlab = "Anaemia Status", ylab = "Percentage")
# Barplot for females with percentages
barplot(y_percentage, beside = TRUE, col = c("lightgreen", "red"),
        legend = rownames(y_percentage), main = "Anaemia in Females",
        xlab = "Anaemia Status", ylab = "Percentage")
```



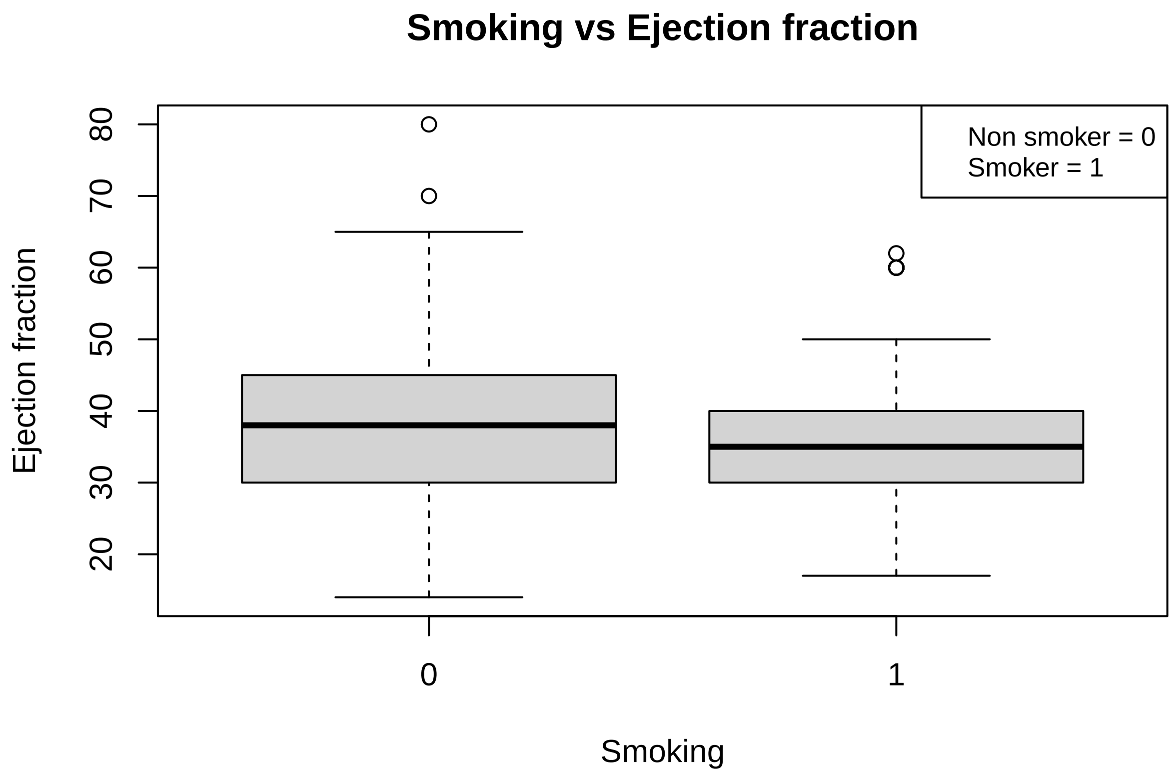
Among male patients around 40% had anaemia and among female around 50% had anaemia.That may mean that females are more prone to anaemia.

```
df_males <- subset(df, sex == 1)
df_females <- subset(df, sex == 0)

# Create a table for diabetes and sex
x <- table(df_males$diabetes, df_males$sex)
y <- table(df_females$diabetes, df_females$sex)
x_percentage <- prop.table(x, margin = 2) * 100
y_percentage <- prop.table(y, margin = 2) * 100  # Calculate percentages across columns (sex)

par(mfrow=c(1,2))
# Barplot for males with percentages
barplot(x_percentage, beside = TRUE, col = c("lightgreen", "red"),
        legend = rownames(y_percentage), main = "Diabetes in Males",
        xlab = "Diabetes Status", ylab = "Percentage")
# Barplot for females with percentages
barplot(y_percentage, beside = TRUE, col = c("lightgreen", "red"),
        legend = rownames(y_percentage), main = "Diabetes in Females",
        xlab = "Diabetes Status", ylab = "Percentage")
```



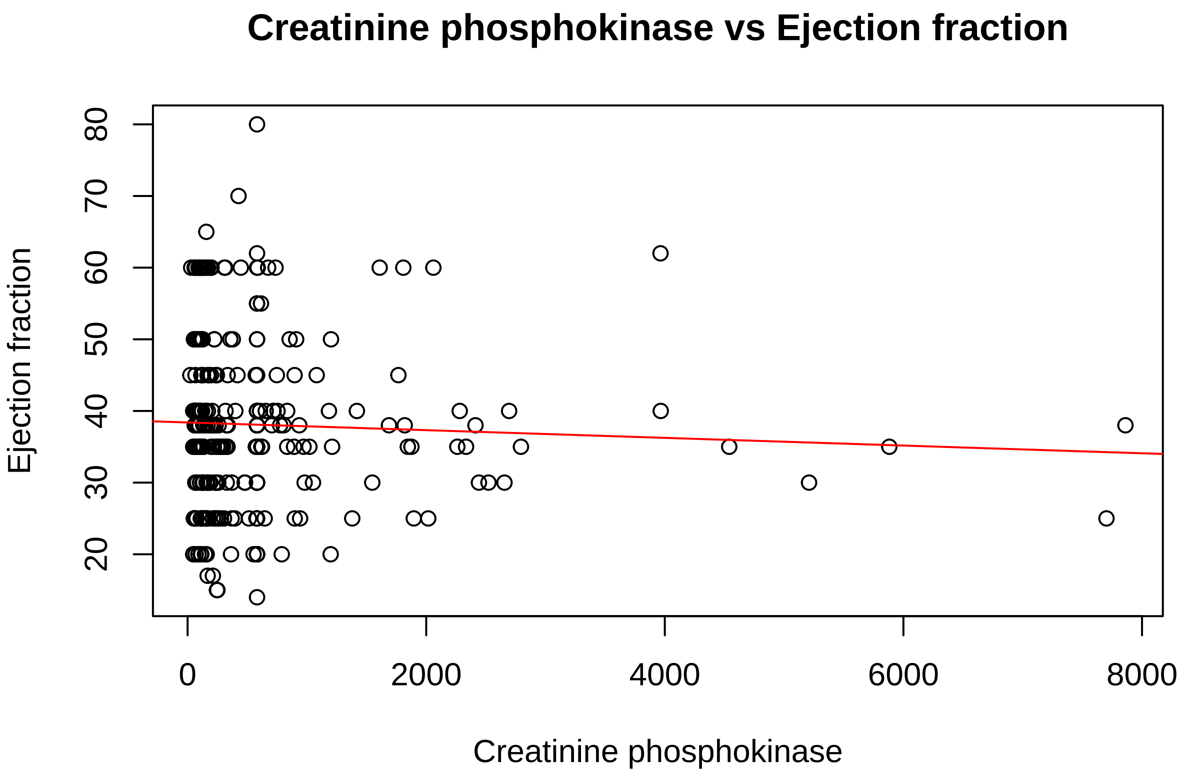
Among male patients around 35% had diabetes and among female around 52% had diabetes.That may mean that females are more prone to diabetes.

```
#Smoking vs Ejection fraction
boxplot(df$ejection_fraction ~ df$smoking, main = "Smoking vs Ejection fraction", xlab = "Smoking", ylal
legend("topright", legend = c("Non smoker = 0", "Smoker = 1"),cex=0.8)
```



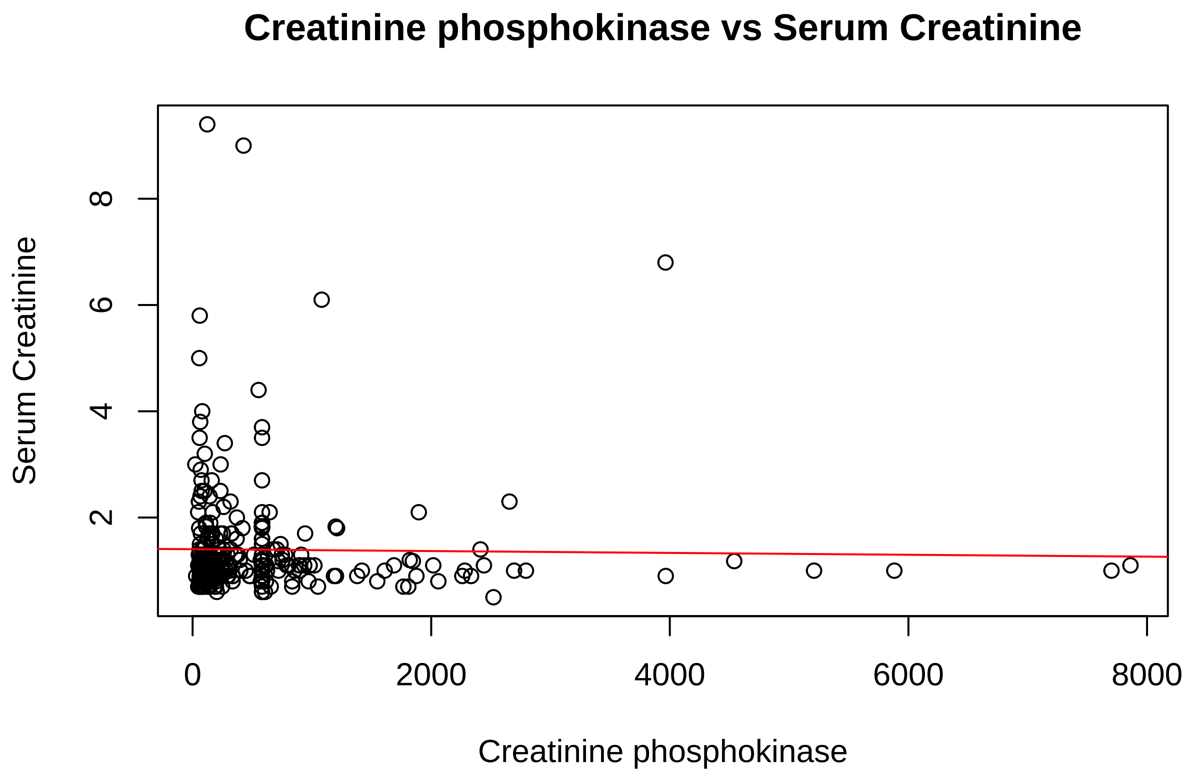
Smoker patients had low value of ejection fraction, meaning that smoking may cause decrease in the pumping capacity of heart.

```
#Creatinine phosphokinase vs Ejection fraction
plot(x=df$creatinine_phosphokinase,y=df$ejection_fraction,main="Creatinine phosphokinase vs Ejection fra
abline(lm(df$ejection_fraction~df$creatinine_phosphokinase),col="red")
```

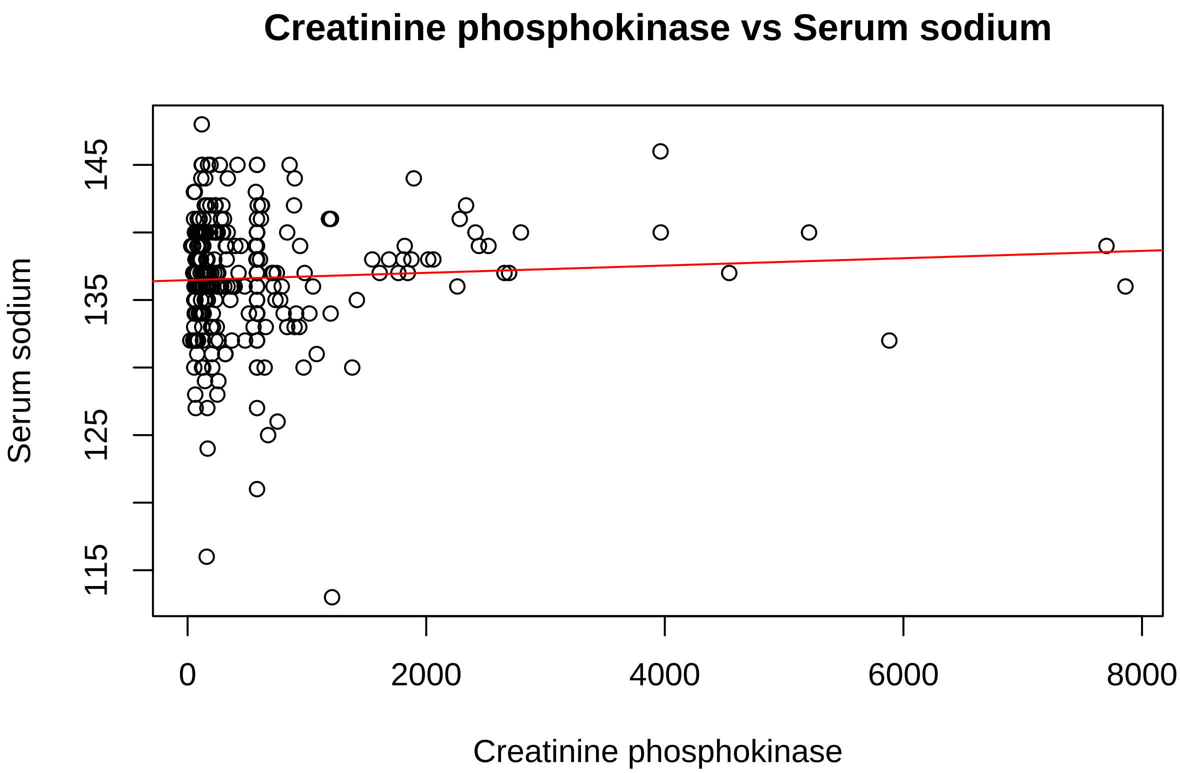


We can see from the graph that as the CPK level increases ejection fraction decreases representing that blood pumping capacity of heart decrease whenever heart injury occurs.

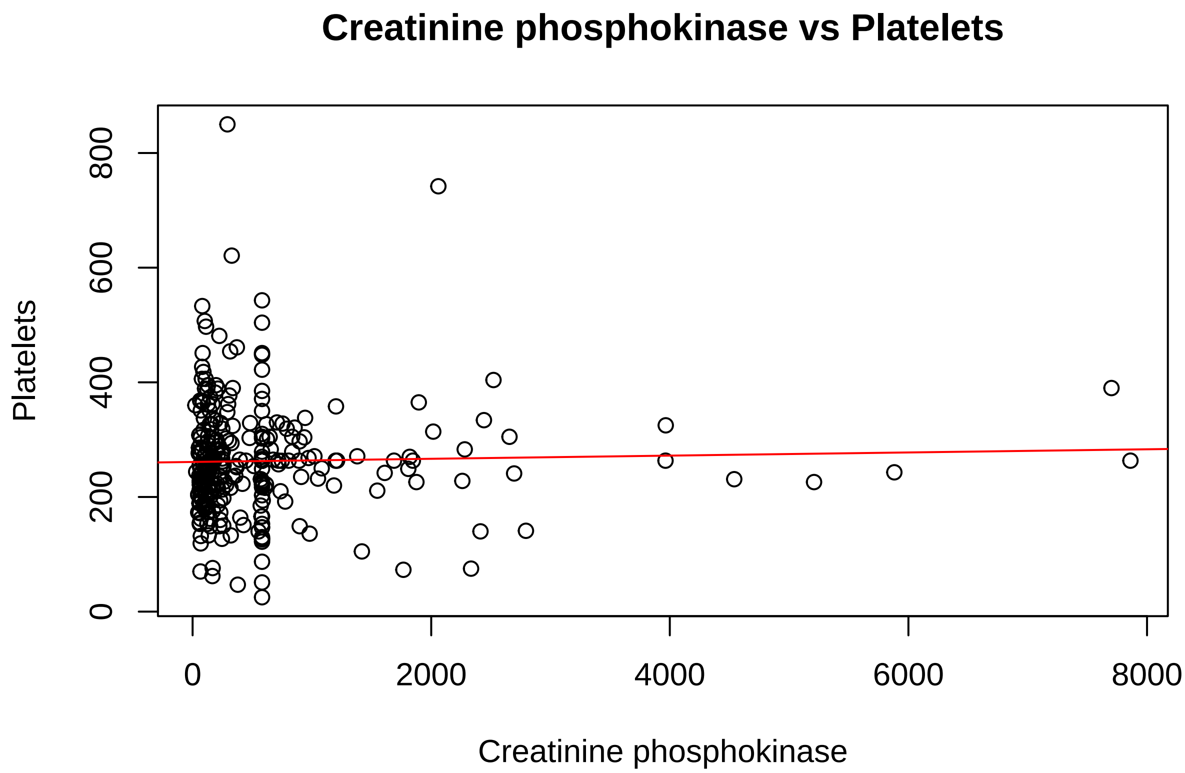
```
#Creatinine phosphokinase vs Serum Creatinine
plot(x=df$creatinine_phosphokinase,y=df$serum_creatinine,main="Creatinine phosphokinase vs Serum Creati
abline(lm(df$serum_creatinine~df$creatinine_phosphokinase),col="red")
```




```
#Creatinine phosphokinase vs Serum sodium
plot(x=df$creatinine_phosphokinase,y=df$serum_sodium,main="Creatinine phosphokinase vs Serum sodium",xla
abline(lm(df$serum_sodium~df$creatinine_phosphokinase),col="red")
```




```
#Creatinine phosphokinase vs Platelets
plot(x=df$creatinine_phosphokinase,y=df$platelets,main="Creatinine phosphokinase vs Platelets",xlab="Cre
abline(lm(df$platelets~df$creatinine_phosphokinase),col="red")
```



Key findings: 1)Ejection fraction, Serum sodium and Serum creatinine can be considered as important factors to predict survival of patients. 2)Females are more prone to anaemia and diabetes than males. 3)Smoking can cause decrease in pumping capacity of heart. 4)Presence of CPK enzyme may be considered for detection of heart injury.

Splitting Dataset into training and testing data

```
train_indices <- sample(1:nrow(df), 0.75 * nrow(df),replace = F)
train_data <- df[train_indices, ]
test_data <- df[-train_indices, ]
train_data
```

```
##     age anaemia creatinine_phosphokinase diabetes ejection_fraction
## 111  85       0                      129        0                60
## 48   60       0                      582        1                38
## 229  65       0                       56        0                25
## 259  45       1                       66        1                25
## 78   42       0                      102        1                40
## 170  70       0                      835        0                35
## 138  68       1                      646        0                25
## 226  75       0                      675        1                60
## 236  77       1                      109        0                50
## 230  72       0                      211        0                25
## 206  50       1                      167        1                45
## 285  50       1                       54        0                40
## 185  58       1                      145        0                25
```

```
## 197  45         0                        582         1                38
## 40   60         0                        235         1                38
## 98   70         1                         59         0                60
## 205  78         1                         64         0                40
## 280  55         0                         84         1                38
## 270  40         0                        582         1                35
## 9    65         0                        157         0                65
## 210  49         0                        972         1                35
## 265  61         0                        582         1                38
## 103  80         0                        898         0                25
## 80   55         0                        336         0                45
## 36   69         0                        582         1                35
## 261  55         0                         66         0                40
## 11   75         1                         81         0                38
## 212  50         0                        582         0                62
## 153  50         0                        115         0                45
## 288  45         0                        582         1                55
## 41   70         0                        582         0                20
## 188  60         0                       1896         1                25
## 174  50         1                        115         0                20
## 14   50         1                        168         0                38
## 239  65         1                        720         1                40
## 156  60         1                        231         1                25
## 152  62         0                         30         1                60
## 44   72         0                        127         1                50
## 86   51         0                         78         0                50
## 211  70         0                        212         1                17
## 220  55         0                        582         1                35
## 282  70         0                        582         0                40
## 108  45         1                       1876         1                35
## 17   87         1                        149         0                38
## 70   65         0                        113         1                25
## 268  56         1                        135         1                38
## 25   75         0                        582         1                30
## 100  63         1                         61         1                40
## 297  45         0                       2060         1                60
## 207  40         1                        101         0                40
## 298  45         0                       2413         0                38
## 74   65         0                        224         1                50
## 159  85         1                        910         0                50
## 42   50         0                        124         1                30
## 296  55         0                       1820         0                38
## 53   60         0                       3964         1                62
## 1    75         0                        582         0                20
## 221  73         0                        582         0                20
## 187  50         0                        582         0                50
## 99   60         1                        156         1                25
## 96   58         1                        133         0                60
## 73   85         0                       5882         0                35
## 45   60         1                        588         1                60
## 72   58         0                        582         1                35
## 178  49         1                         69         0                50
## 274  42         0                         64         0                40
## 284  65         0                       1688         0                38
```

```
## 233  40        1                       129        0                  35
## 271  44        0                       582        1                  30
## 64   45        0                       582        0                  35
## 281  70        0                      2695        1                  40
## 235  53        1                       582        0                  45
## 147  52        0                       132        0                  30
## 124  60        1                       582        0                  30
## 33   50        1                       249        1                  35
## 276  45        0                       582        0                  38
## 175  65        0                       198        1                  35
## 149  75        1                       582        0                  30
## 47   51        0                      1380        0                  25
## 266  50        1                       298        0                  35
## 137  65        1                        59        1                  60
## 267  55        0                      1199        0                  20
## 57   70        1                        75        0                  35
## 102  75        0                       582        0                  45
## 262  62        1                       655        0                  40
## 208  85        0                       212        0                  38
## 49   80        1                       553        0                  20
## 141  80        0                       805        0                  38
## 232  70        0                        93        0                  35
## 37   90        1                        60        1                  50
## 68   72        1                       110        0                  25
## 77   70        0                        92        0                  60
## 143  50        0                       482        1                  30
## 51   68        1                       577        0                  25
## 290  90        1                       337        0                  38
## 162  45        1                       130        0                  35
## 81   70        0                        69        0                  40
## 157  52        1                        58        0                  35
## 249  40        0                       624        0                  35
## 58   60        1                       607        0                  40
## 248  64        0                       143        0                  25
## 244  73        1                      1185        0                  40
## 5    65        1                       160        1                  20
## 139  62        0                       281        1                  35
## 2    55        0                      7861        0                  38
## 129  61        0                       248        0                  30
## 105  60        0                        53        0                  50
## 134  63        0                       193        0                  60
## 200  60        0                      1211        1                  35
## 264  68        1                       157        1                  60
## 287  60        0                       253        0                  35
## 255  53        1                       446        0                  60
## 84   79        1                        55        0                  50
## 299  50        0                       196        0                  45
## 112  55        0                        60        0                  35
## 18   45        0                       582        0                  14
## 136  75        0                       582        0                  40
## 158  50        0                       250        0                  25
## 195  45        0                       582        0                  20
## 28   70        0                       122        1                  45
## 250  53        0                       207        1                  40
```

```
## 180  55         0                       835        0                 40
## 12   62         0                       231        0                 25
## 75   69         0                       582        0                 20
## 161  66         1                        72        0                 40
## 272  51         0                       582        1                 40
## 140  50         0                      1548        0                 30
## 198  65         0                       167        0                 30
## 31   94         0                       582        1                 38
## 62   50         0                       318        0                 40
## 173  70         1                       171        0                 60
## 181  40         0                       478        1                 30
## 107  55         0                       748        0                 45
## 209  60         1                      2281        1                 40
## 121  60         1                       737        0                 60
## 21   65         1                        52        0                 25
## 55   60         1                       260        1                 38
## 128  58         1                       200        1                 60
## 204  60         0                        59        0                 25
## 16   82         1                       379        0                 50
## 3    65         0                       146        0                 20
## 177  69         0                      1419        0                 40
## 85   59         1                       280        1                 25
## 6    90         1                        47        0                 40
## 63   55         0                       109        0                 35
## 241  70         0                        81        1                 35
## 127  46         0                       168        1                 17
## 258  58         0                       132        1                 38
## 247  55         0                      2017        0                 25
## 256  52         1                       191        1                 30
## 172  52         0                      3966        0                 40
## 123  60         0                        96        1                 38
## 283  42         0                        64        0                 30
## 231  60         0                       166        0                 30
## 148  64         0                      1610        0                 60
## 186  60         1                       104        1                 30
## 183  65         0                       395        1                 25
## 67   42         1                       250        1                 15
## 279  50         1                      1051        1                 30
## 234  53         1                       707        0                 38
## 66   60         0                        68        0                 20
## 93   42         0                       582        0                 60
## 39   60         0                      2656        1                 30
## 146  50         0                       185        0                 30
## 192  64         1                        62        0                 60
## 245  54         0                       582        1                 38
## 46   50         0                       582        1                 38
## 27   95         1                       112        0                 40
## 20   48         1                       582        1                 55
## 110  45         0                       292        1                 35
## 109  63         0                       936        0                 38
## 60   72         0                       364        1                 20
## 131  53         1                      1808        0                 60
## 165  45         0                      2442        1                 30
## 160  59         1                       129        0                 45
```

```
## 130  53       1                        270        1                 35
## 257  65       0                        326        0                 38
## 224  47       0                        582        0                 25
## 168  59       0                         66        1                 20
## 218  54       1                        427        0                 70
## 71   41       0                        148        0                 40
## 89   44       0                         84        1                 40
## 227  58       1                         57        0                 25
## 125  60       0                        582        0                 40
## 194  73       1                        231        1                 30
## 213  78       0                        224        0                 50
## 166  80       0                        776        1                 38
## 199  50       1                        582        1                 20
## 294  63       1                        103        1                 35
## 69   70       0                        161        0                 25
## 29   58       1                         60        0                 38
## 133  46       0                        719        0                 40
## 118  85       1                        102        0                 60
## 24   53       0                         63        1                 60
## 13   45       1                        981        0                 30
## 94   60       1                        154        0                 25
## 26   80       0                        148        1                 38
## 50   57       1                        129        0                 30
## 176  60       1                         95        0                 60
## 151  72       0                        233        0                 45
## 115  60       1                        754        1                 40
## 76   60       1                         47        0                 20
## 182  59       1                        176        1                 25
## 286  55       1                        170        1                 40
## 92   60       0                        897        1                 45
## 32   85       0                         23        0                 45
## 38   82       1                        855        1                 50
## 120  86       0                        582        0                 38
## 116  58       1                        400        0                 40
## 242  65       0                        582        1                 30
## 190  40       0                        244        0                 45
## 223  42       1                         86        0                 35
## 201  63       1                       1767        0                 45
## 10   80       1                        123        0                 35
## 167  53       0                        196        0                 60
## 228  55       1                       2794        0                 35
## 88   65       1                         68        1                 60
## 135  81       0                       4540        0                 35
## 19   70       1                        125        0                 25
## 15   49       1                         80        0                 30
## 101  65       1                        305        0                 25
## 292  60       0                        320        0                 35
## 132  60       1                       1082        1                 45
## 196  77       1                        418        0                 45
##     high_blood_pressure platelets serum_creatinine serum_sodium sex smoking
## 111                   0   306.000             1.20          132   1       1
## 48                    1   451.000             0.60          138   1       1
## 229                   0   237.000             5.00          130   0       0
## 259                   0   233.000             0.80          135   1       0
```

```
## 78       0 237.000   1.20   140 1 0
## 170      1 305.000   0.80   133 0 0
## 138      0 305.000   2.10   130 1 0
## 226      0 265.000   1.40   125 0 0
## 236      1 406.000   1.10   137 1 0
## 230      0 274.000   1.20   134 0 0
## 206      0 362.000   1.00   136 0 0
## 285      0 279.000   0.80   141 1 0
## 185      0 219.000   1.20   137 1 1
## 197      1 263.358   1.18   137 0 0
## 40       0 329.000   3.00   142 0 0
## 98       0 255.000   1.10   136 0 0
## 205      0 277.000   0.70   137 1 1
## 280      0 451.000   1.30   136 0 0
## 270      0 222.000   1.00   132 1 0
## 9        0 263.358   1.50   138 0 0
## 210      1 268.000   0.80   130 0 0
## 265      0 147.000   1.20   141 1 0
## 103      0 149.000   1.10   144 1 1
## 80       1 324.000   0.90   140 0 0
## 36       0 228.000   3.50   134 1 0
## 261      0 203.000   1.00   138 1 0
## 11       1 368.000   4.00   131 1 1
## 212      1 147.000   0.80   140 1 1
## 153      1 184.000   0.90   134 1 1
## 288      0 543.000   1.00   132 0 0
## 41       1 263.358   1.83   134 1 1
## 188      0 365.000   2.10   144 0 0
## 174      0 189.000   0.80   139 1 0
## 14       1  76.000   1.10   137 1 0
## 239      0 257.000   1.00   136 0 0
## 156      0 194.000   1.70   140 1 0
## 152      1 244.000   0.90   139 1 0
## 44       1 218.000   1.00   134 1 0
## 86       0 406.000   0.70   140 1 0
## 211      1 389.000   1.00   136 1 1
## 220      1 371.000   0.70   140 0 0
## 282      0  51.000   2.70   136 1 1
## 108      0 226.000   0.90   138 1 0
## 17       0 262.000   0.90   140 1 0
## 70       0 497.000   1.83   135 1 0
## 268      0 133.000   1.70   140 1 0
## 25       1 263.358   1.83   134 0 0
## 100      0 221.000   1.10   140 0 0
## 297      0 742.000   0.80   138 0 0
## 207      0 226.000   0.80   141 0 0
## 298      0 140.000   1.40   140 1 1
## 74       0 149.000   1.30   137 1 1
## 159      0 235.000   1.30   134 1 0
## 42       1 153.000   1.20   136 0 1
## 296      0 270.000   1.20   139 0 0
## 53       0 263.358   6.80   146 0 0
## 1        1 265.000   1.90   130 1 0
## 221      0 263.358   1.83   134 1 0
```

```
## 187                  0   153.000              0.60          134   0       0
## 99                   1   318.000              1.20          137   0       0
## 96                   1   219.000              1.00          141   1       0
## 73                   0   243.000              1.00          132   1       1
## 45                   0   194.000              1.10          142   0       0
## 72                   0   122.000              0.90          139   1       1
## 178                  0   132.000              1.00          140   0       0
## 274                  0   189.000              0.70          140   1       0
## 284                  0   263.358              1.10          138   1       1
## 233                  0   255.000              0.90          137   1       0
## 271                  1   263.358              1.60          130   1       1
## 64                   0   385.000              1.00          145   1       0
## 281                  0   241.000              1.00          137   1       0
## 235                  0   305.000              1.10          137   1       1
## 147                  0   218.000              0.70          136   1       1
## 124                  1   127.000              0.90          145   0       0
## 33                   1   319.000              1.00          128   0       0
## 276                  1   422.000              0.80          137   0       0
## 175                  1   281.000              0.90          137   1       1
## 149                  0   225.000              1.83          134   1       0
## 47                   1   271.000              0.90          130   1       0
## 266                  0   362.000              0.90          140   1       1
## 137                  0   172.000              0.90          137   0       0
## 267                  0   263.358              1.83          134   1       1
## 57                   0   223.000              2.70          138   1       1
## 102                  1   263.358              1.18          137   1       0
## 262                  0   283.000              0.70          133   0       0
## 208                  0   186.000              0.90          136   1       0
## 49                   1   140.000              4.40          133   1       0
## 141                  0   263.358              1.10          134   1       0
## 232                  0   185.000              1.10          134   1       1
## 37                   0   226.000              1.00          134   1       0
## 68                   0   274.000              1.00          140   1       1
## 77                   1   317.000              0.80          140   0       1
## 143                  0   329.000              0.90          132   0       0
## 51                   1   166.000              1.00          138   1       0
## 290                  0   390.000              0.90          144   0       0
## 162                  0   174.000              0.80          139   1       1
## 81                   0   293.000              1.70          136   0       0
## 157                  0   277.000              1.40          136   0       0
## 249                  0   301.000              1.00          142   1       1
## 58                   0   216.000              0.60          138   1       1
## 248                  0   246.000              2.40          135   1       0
## 244                  1   220.000              0.90          141   0       0
## 5                    0   327.000              2.70          116   0       0
## 139                  0   221.000              1.00          136   0       0
## 2                    0   263.358              1.10          136   1       0
## 129                  1   267.000              0.70          136   1       1
## 105                  1   286.000              2.30          143   0       0
## 134                  1   295.000              1.30          145   1       1
## 200                  0   263.358              1.80          113   1       1
## 264                  0   208.000              1.00          140   0       0
## 287                  0   279.000              1.70          140   1       0
## 255                  1   263.358              1.00          139   1       0
```

```
## 84    1  172.000   1.80   133  1  0
## 299   0  395.000   1.60   136  1  1
## 112   0  228.000   1.20   135  1  1
## 18    0  166.000   0.80   127  1  0
## 136   0  263.358   1.18   137  1  0
## 158   0  262.000   1.00   136  1  1
## 195   1  126.000   1.60   135  1  0
## 28    1  284.000   1.30   136  1  1
## 250   0  223.000   1.20   130  0  0
## 180   0  279.000   0.70   140  1  1
## 12    1  253.000   0.90   140  1  1
## 75    0  266.000   1.20   134  1  1
## 161   1  242.000   1.20   134  1  0
## 272   0  221.000   0.90   134  0  0
## 140   1  211.000   0.80   138  1  0
## 198   0  259.000   0.80   138  0  0
## 31    1  263.358   1.83   134  1  0
## 62    1  216.000   2.30   131  0  0
## 173   1  176.000   1.10   145  1  1
## 181   0  303.000   0.90   136  1  0
## 107   0  263.000   1.30   137  1  0
## 209   0  283.000   1.00   141  0  0
## 121   1  210.000   1.50   135  1  1
## 21    1  276.000   1.30   137  0  0
## 55    0  255.000   2.20   132  0  1
## 128   0  300.000   0.80   137  0  0
## 204   1  212.000   3.50   136  1  1
## 16    0   47.000   1.30   136  1  0
## 3     0  162.000   1.30   129  1  1
## 177   0  105.000   1.00   135  1  1
## 85    1  302.000   1.00   141  0  0
## 6     1  204.000   2.10   132  1  1
## 63    0  254.000   1.10   139  1  1
## 241   1  533.000   1.30   139  0  0
## 127   1  271.000   2.10   124  0  0
## 258   1  253.000   1.00   139  1  0
## 247   0  314.000   1.10   138  1  0
## 256   1  334.000   1.00   142  1  1
## 172   0  325.000   0.90   140  1  1
## 123   0  228.000   0.75   140  0  0
## 283   0  215.000   3.80   128  1  1
## 231   0   62.000   1.70   127  0  0
## 148   0  242.000   1.00   137  1  0
## 186   0  389.000   1.50   136  1  0
## 183   0  265.000   1.20   136  1  1
## 67    0  213.000   1.30   136  0  0
## 279   0  232.000   0.70   136  0  0
## 234   0  330.000   1.40   137  1  1
## 66    0  119.000   2.90   127  1  1
## 93    0  263.358   1.18   137  0  0
## 39    0  305.000   2.30   137  1  0
## 146   0  266.000   0.70   141  1  1
## 192   0  309.000   1.50   135  0  0
## 245   0  264.000   1.80   134  1  0
```

```
## 46                         0   310.000                    1.90             135   1        1
## 27                         1   196.000                    1.00             138   0        0
## 20                         0    87.000                    1.90             121   0        0
## 110                        0   850.000                    1.30             142   1        1
## 109                        0   304.000                    1.10             133   1        1
## 60                         1   254.000                    1.30             136   1        1
## 131                        1   249.000                    0.70             138   1        1
## 165                        0   334.000                    1.10             139   1        0
## 160                        1   362.000                    1.10             139   1        1
## 130                        0   227.000                    3.40             145   1        0
## 257                        0   294.000                    1.70             139   0        0
## 224                        0   130.000                    0.80             134   1        0
## 168                        0    70.000                    2.40             134   1        0
## 218                        1   151.000                    9.00             137   0        0
## 71                         0   374.000                    0.80             140   1        1
## 89                         1   235.000                    0.70             139   1        0
## 227                        0   189.000                    1.30             132   1        1
## 125                        0   217.000                    3.70             134   1        0
## 194                        0   160.000                    1.18             142   1        1
## 213                        0   481.000                    1.40             138   1        1
## 166                        1   192.000                    1.30             135   0        0
## 199                        1   279.000                    1.00             134   0        0
## 294                        0   179.000                    0.90             136   1        1
## 69                         0   244.000                    1.20             142   0        0
## 29                         0   153.000                    5.80             134   1        0
## 133                        1   263.358                    1.18             137   0        0
## 118                        0   507.000                    3.20             138   0        0
## 24                         0   368.000                    0.80             135   1        0
## 13                         0   136.000                    1.10             137   1        0
## 94                         0   210.000                    1.70             135   1        0
## 26                         0   149.000                    1.90             144   1        1
## 50                         0   395.000                    1.00             140   0        0
## 176                        0   337.000                    1.00             138   1        1
## 151                        1   235.000                    2.50             135   0        0
## 115                        1   328.000                    1.20             126   1        0
## 76                         0   204.000                    0.70             139   1        1
## 182                        0   221.000                    1.00             136   1        1
## 286                        0   336.000                    1.20             135   1        0
## 92                         0   297.000                    1.00             133   1        0
## 32                         0   360.000                    3.00             132   1        0
## 38                         1   321.000                    1.00             145   0        0
## 120                        0   263.358                    1.83             134   0        0
## 116                        0   164.000                    1.00             139   0        0
## 242                        0   249.000                    1.30             136   1        1
## 190                        1   275.000                    0.90             140   0        0
## 223                        0   365.000                    1.10             139   1        1
## 201                        0    73.000                    0.70             137   1        0
## 10                         1   388.000                    9.40             133   1        1
## 167                        0   220.000                    0.70             133   1        1
## 228                        1   141.000                    1.00             140   1        0
## 88                         1   304.000                    0.80             140   1        0
## 135                        0   231.000                    1.18             137   1        1
## 19                         1   237.000                    1.00             140   0        0
## 15                         1   427.000                    1.00             138   0        0
```

```
## 101                   0   298.000             1.10          141   1        0
## 292                   0   133.000             1.40          139   1        0
## 132                   0   250.000             6.10          131   1        0
## 196                   0   223.000             1.80          145   1        0
##     time DEATH_EVENT
## 111   90           1
## 48    40           1
## 229  207           0
## 259  230           0
## 78    74           0
## 170  145           0
## 138  108           0
## 226  205           0
## 236  209           0
## 230  207           0
## 206  187           0
## 285  250           0
## 185  170           1
## 197  185           0
## 40    30           1
## 98    85           0
## 205  187           0
## 280  246           0
## 270  244           0
## 9     10           1
## 210  187           0
## 265  237           0
## 103   87           0
## 80    74           0
## 36    30           1
## 261  233           0
## 11    10           1
## 212  192           0
## 153  118           0
## 288  250           0
## 41    31           1
## 188  172           1
## 174  146           0
## 14    11           1
## 239  210           0
## 156  120           0
## 152  117           0
## 44    33           0
## 86    79           0
## 211  188           0
## 220  197           0
## 282  250           0
## 108   88           0
## 17    14           1
## 70    67           1
## 268  244           0
## 25    23           1
## 100   86           0
## 297  278           0
```

```
## 207  187              0
## 298  280              0
## 74    72              0
## 159  121              0
## 42    32              1
## 296  271              0
## 53    43              1
## 1      4              1
## 221  198              1
## 187  172              1
## 99    85              0
## 96    83              0
## 73    72              1
## 45    33              1
## 72    71              0
## 178  147              0
## 274  245              0
## 284  250              0
## 233  209              0
## 271  244              0
## 64    61              1
## 281  247              0
## 235  209              0
## 147  112              0
## 124   95              0
## 33    28              1
## 276  245              0
## 175  146              0
## 149  113              1
## 47    38              1
## 266  240              0
## 137  107              0
## 267  241              1
## 57    54              0
## 102   87              0
## 262  233              0
## 208  187              0
## 49    41              1
## 141  109              1
## 232  208              0
## 37    30              1
## 68    65              1
## 77    74              0
## 143  109              0
## 51    43              1
## 290  256              0
## 162  121              0
## 81    75              0
## 157  120              0
## 249  214              0
## 58    54              0
## 248  214              0
## 244  213              0
## 5      8              1
```

```
## 139  108           0
## 2      6           1
## 129  104           0
## 105   87           0
## 134  107           0
## 200  186           0
## 264  237           0
## 287  250           0
## 255  215           0
## 84    78           0
## 299  285           0
## 112   90           0
## 18    14           1
## 136  107           0
## 158  120           0
## 195  180           1
## 28    26           1
## 250  214           0
## 180  147           0
## 12    10           1
## 75    73           1
## 161  121           0
## 272  244           0
## 140  108           0
## 198  186           0
## 31    27           1
## 62    60           1
## 173  146           0
## 181  148           0
## 107   88           0
## 209  187           0
## 121   95           0
## 21    16           0
## 55    45           1
## 128  104           0
## 204  187           0
## 16    13           1
## 3      7           1
## 177  147           0
## 85    78           1
## 6      8           1
## 63    60           0
## 241  212           0
## 127  100           1
## 258  230           0
## 247  214           1
## 256  216           0
## 172  146           0
## 123   95           0
## 283  250           0
## 231  207           1
## 148  113           0
## 186  171           1
## 183  154           1
```

```
## 67     65              1
## 279   246              0
## 234   209              0
## 66     64              1
## 93     82              0
## 39     30              0
## 146   112              0
## 192   174              0
## 245   213              0
## 46     35              1
## 27     24              1
## 20     15              1
## 110    88              0
## 109    88              0
## 60     59              1
## 131   106              0
## 165   129              1
## 160   121              0
## 130   105              0
## 257   220              0
## 224   201              0
## 168   135              1
## 218   196              1
## 71     68              0
## 89     79              0
## 227   205              0
## 125    96              1
## 194   180              0
## 213   192              0
## 166   130              1
## 199   186              0
## 294   270              0
## 69     66              1
## 29     26              1
## 133   107              0
## 118    94              0
## 24     22              0
## 13     11              1
## 94     82              1
## 26     23              1
## 50     42              1
## 176   146              0
## 151   115              1
## 115    91              0
## 76     73              1
## 182   150              1
## 286   250              0
## 92     80              0
## 32     28              1
## 38     30              1
## 120    95              1
## 116    91              0
## 242   212              0
## 190   174              0
```

```
## 223  201           0
## 201  186           0
## 10    10           1
## 167  134           0
## 228  206           0
## 88    79           0
## 135  107           0
## 19    15           1
## 15    12           0
## 101   87           0
## 292  258           0
## 132  107           0
## 196  180           1
```

```
test_data
```

```
##     age anaemia creatinine_phosphokinase diabetes ejection_fraction
## 4    50       1                      111        0                20
## 7    75       1                      246        0                15
## 8    60       1                      315        1                60
## 22   65       1                      128        1                30
## 23   68       1                      220        0                35
## 30   82       0                       70        1                30
## 34   50       1                      159        1                30
## 35   65       0                       94        1                50
## 43   70       0                      571        1                45
## 52   53       1                       91        0                20
## 54   70       1                       69        1                50
## 56   95       1                      371        0                30
## 59   49       0                      789        0                20
## 61   45       0                     7702        1                25
## 65   45       0                      582        0                80
## 79   75       1                      203        1                38
## 82   67       0                      582        0                50
## 83   60       1                       76        1                25
## 87   55       0                       47        0                35
## 90   57       1                      115        0                25
## 91   70       0                       66        1                45
## 95   58       0                      144        1                38
## 97   63       1                      514        1                25
## 104  42       0                     5209        0                30
## 106  72       1                      328        0                30
## 113  50       0                      369        1                25
## 114  70       1                      143        0                60
## 117  60       1                       96        1                60
## 119  65       1                      113        1                60
## 122  66       1                       68        1                38
## 126  43       1                      358        0                50
## 142  46       1                      291        0                35
## 144  61       1                       84        0                40
## 145  72       1                      943        0                25
## 150  60       0                     2261        0                35
## 154  50       0                     1846        1                35
## 155  65       1                      335        0                35
```

```
## 163  63        1                        582        0                40
## 164  50        1                       2334        1                35
## 169  65        0                        582        1                40
## 171  51        1                        582        1                35
## 179  63        1                        122        1                60
## 184  75        0                         99        0                38
## 189  60        1                        151        1                40
## 191  80        0                        582        1                35
## 193  50        1                        121        1                40
## 202  45        0                        308        1                60
## 203  70        0                         97        0                60
## 214  48        1                        131        1                30
## 215  65        1                        135        0                35
## 216  73        0                        582        0                35
## 217  70        0                       1202        0                50
## 219  68        1                       1021        1                35
## 222  65        0                        118        0                50
## 225  58        0                        582        1                25
## 237  75        0                        119        0                50
## 238  70        0                        232        0                30
## 240  55        1                        180        0                45
## 243  40        0                         90        0                35
## 246  61        1                         80        1                38
## 251  50        0                       2522        0                30
## 252  55        0                        572        1                35
## 253  50        0                        245        0                45
## 254  70        0                         88        1                35
## 260  53        0                         56        0                50
## 263  65        1                        258        1                25
## 269  45        0                        582        1                38
## 273  67        0                        213        0                38
## 275  60        1                        257        1                30
## 277  70        0                        618        0                35
## 278  70        0                        582        1                38
## 289  65        0                        892        1                35
## 291  45        0                        615        1                55
## 293  52        0                        190        1                38
## 295  62        0                         61        1                38
##     high_blood_pressure platelets serum_creatinine serum_sodium sex smoking
## 4                     0   210.000             1.90          137   1       0
## 7                     0   127.000             1.20          137   1       0
## 8                     0   454.000             1.10          131   1       1
## 22                    1   297.000             1.60          136   0       0
## 23                    1   289.000             0.90          140   1       1
## 30                    0   200.000             1.20          132   1       1
## 34                    0   302.000             1.20          138   0       0
## 35                    1   188.000             1.00          140   1       0
## 43                    1   185.000             1.20          139   1       1
## 52                    1   418.000             1.40          139   0       0
## 54                    1   351.000             1.00          134   0       0
## 56                    0   461.000             2.00          132   1       0
## 59                    1   319.000             1.10          136   1       1
## 61                    1   390.000             1.00          139   1       0
## 65                    0   263.358             1.18          137   0       0
```

```
## 79                        1   283.000             0.60           131   1        1
## 82                        0   263.358             1.18           137   1        1
## 83                        0   196.000             2.50           132   0        0
## 87                        1   173.000             1.10           137   1        0
## 90                        1   181.000             1.10           144   1        0
## 91                        0   249.000             0.80           136   1        1
## 95                        1   327.000             0.70           142   0        0
## 97                        1   254.000             1.30           134   1        0
## 104                       0   226.000             1.00           140   1        1
## 106                       1   621.000             1.70           138   0        1
## 113                       0   252.000             1.60           136   1        0
## 114                       0   351.000             1.30           137   0        0
## 117                       1   271.000             0.70           136   0        0
## 119                       1   203.000             0.90           140   0        0
## 122                       1   162.000             1.00           136   0        0
## 126                       0   237.000             1.30           135   0        0
## 142                       0   348.000             0.90           140   0        0
## 144                       1   229.000             0.90           141   0        0
## 145                       1   338.000             1.70           139   1        1
## 150                       1   228.000             0.90           136   1        0
## 154                       0   263.358             1.18           137   1        1
## 155                       1   235.000             0.80           136   0        0
## 163                       0   448.000             0.90           137   1        1
## 164                       0    75.000             0.90           142   0        0
## 169                       0   270.000             1.00           138   0        0
## 171                       0   263.358             1.50           136   1        1
## 179                       0   267.000             1.20           145   1        0
## 184                       1   224.000             2.50           134   1        0
## 189                       1   201.000             1.00           136   0        0
## 191                       0   350.000             2.10           134   1        0
## 193                       0   260.000             0.70           130   1        0
## 202                       1   377.000             1.00           136   1        0
## 203                       1   220.000             0.90           138   1        0
## 214                       1   244.000             1.60           130   0        0
## 215                       1   290.000             0.80           134   1        0
## 216                       1   203.000             1.30           134   1        0
## 217                       1   358.000             0.90           141   0        0
## 219                       0   271.000             1.10           134   1        0
## 222                       0   194.000             1.10           145   1        1
## 225                       0   504.000             1.00           138   1        0
## 237                       1   248.000             1.10           148   1        0
## 238                       0   173.000             1.20           132   1        0
## 240                       0   263.358             1.18           137   1        1
## 243                       0   255.000             1.10           136   1        1
## 246                       0   282.000             1.40           137   1        0
## 251                       1   404.000             0.50           139   0        0
## 252                       0   231.000             0.80           143   0        0
## 253                       1   274.000             1.00           133   1        0
## 254                       1   236.000             1.20           132   0        0
## 260                       0   308.000             0.70           135   1        1
## 263                       0   198.000             1.40           129   1        0
## 269                       0   302.000             0.90           140   0        0
## 273                       0   215.000             1.20           133   0        0
## 275                       0   150.000             1.00           137   1        1
```

```
## 277                      0   327.000              1.10          142   0        0
## 278                      0    25.100              1.10          140   1        0
## 289                      0   263.358              1.10          142   0        0
## 291                      0   222.000              0.80          141   0        0
## 293                      0   382.000              1.00          140   1        1
## 295                      1   155.000              1.10          143   1        1
##     time DEATH_EVENT
## 4      7           1
## 7     10           1
## 8     10           1
## 22    20           1
## 23    20           1
## 30    26           1
## 34    29           0
## 35    29           1
## 43    33           1
## 52    43           1
## 54    44           1
## 56    50           1
## 59    55           1
## 61    60           1
## 65    63           0
## 79    74           0
## 82    76           0
## 83    77           1
## 87    79           0
## 90    79           0
## 91    80           0
## 95    83           0
## 97    83           0
## 104   87           0
## 106   88           1
## 113   90           0
## 114   90           1
## 117   94           0
## 119   94           0
## 122   95           0
## 126   97           0
## 142  109           0
## 144  110           0
## 145  111           1
## 150  115           0
## 154  119           0
## 155  120           0
## 163  123           0
## 164  126           1
## 169  140           0
## 171  145           0
## 179  147           0
## 184  162           1
## 189  172           0
## 191  174           0
## 193  175           0
## 202  186           0
```

```
## 203  186           0
## 214  193           1
## 215  194           0
## 216  195           0
## 217  196           0
## 219  197           0
## 222  200           0
## 225  205           0
## 237  209           0
## 238  210           0
## 240  211           0
## 243  212           0
## 246  213           0
## 251  214           0
## 252  215           0
## 253  215           0
## 254  215           0
## 260  231           0
## 263  235           1
## 269  244           0
## 273  245           0
## 275  245           0
## 277  245           0
## 278  246           0
## 289  256           0
## 291  257           0
## 293  258           0
## 295  270           0
```

Model development (logistic)

```
logistic_model = glm(DEATH_EVENT~., data=train_data, family="binomial")
summary(logistic_model)
```

```
##
## Call:
## glm(formula = DEATH_EVENT ~ ., family = "binomial", data = train_data)
##
## Coefficients:
##                            Estimate Std. Error z value Pr(>|z|)
## (Intercept)               7.9632799  6.0737111   1.311   0.1898
## age                       0.0434821  0.0172850   2.516   0.0119 *
## anaemia                  -0.3808572  0.4272709  -0.891   0.3727
## creatinine_phosphokinase  0.0001882  0.0002380   0.791   0.4292
## diabetes                  0.2101722  0.4112369   0.511   0.6093
## ejection_fraction        -0.0825491  0.0190516  -4.333 1.47e-05 ***
## high_blood_pressure      -0.2561613  0.4318960  -0.593   0.5531
## platelets                -0.0031861  0.0023648  -1.347   0.1779
## serum_creatinine          0.6122125  0.1903677   3.216   0.0013 **
## serum_sodium             -0.0416713  0.0432340  -0.964   0.3351
## sex                      -0.4533968  0.4677745  -0.969   0.3324
## smoking                  -0.2713557  0.4774305  -0.568   0.5698
## time                     -0.0209163  0.0034518  -6.059 1.37e-09 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 285.62  on 223  degrees of freedom
## Residual deviance: 166.87  on 211  degrees of freedom
## AIC: 192.87
##
## Number of Fisher Scoring iterations: 6
```

Applying this model to test data

```
pred_prob <- predict(logistic_model, newdata = test_data, type = "response")
#Setting threshold probability to 0.5
threshold <- 0.5
test_predictions <- ifelse(pred_prob > threshold, 1, 0)
test_predictions
```

```
##   4   7   8  22  23  30  34  35  43  52  54  56  59  61  65  79  82  83  87  90
##   1   1   0   1   1   1   1   0   1   1   0   1   1   1   0   0   0   1   0   0
##  91  95  97 104 106 113 114 117 119 122 126 142 144 145 150 154 155 163 164 169
##   0   0   1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
## 171 179 184 189 191 193 202 203 214 215 216 217 219 222 225 237 238 240 243 246
##   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
## 251 252 253 254 260 263 269 273 275 277 278 289 291 293 295
##   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Model evaluation

```
library(caret)
```

```
## Loading required package: lattice
```

```
# Create a confusion matrix
conf_matrix <- confusionMatrix(factor(test_predictions), factor(test_data$DEATH_EVENT))

# Display the confusion matrix and accuracy
conf_matrix
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction  0  1
##          0 51 10
##          1  3 11
##
##                Accuracy : 0.8267
##                  95% CI : (0.7219, 0.9043)
##     No Information Rate : 0.72
##     P-Value [Acc > NIR] : 0.02306
```

```
##
##                   Kappa : 0.5214
##
##  Mcnemar's Test P-Value : 0.09609
##
##             Sensitivity : 0.9444
##             Specificity : 0.5238
##          Pos Pred Value : 0.8361
##          Neg Pred Value : 0.7857
##              Prevalence : 0.7200
##          Detection Rate : 0.6800
##    Detection Prevalence : 0.8133
##       Balanced Accuracy : 0.7341
##
##        'Positive' Class : 0
##
```

```
print(paste("Accuracy:", conf_matrix$overall["Accuracy"]))
```

```
## [1] "Accuracy: 0.826666666666667"
```

#Here we obtained an accuracy of 0.85 which is good for predicting survival of patients.

Drawing ROC curve

```
library(pROC)
```

```
## Type 'citation("pROC")' for a citation.
```

```
##
## Attaching package: 'pROC'
```

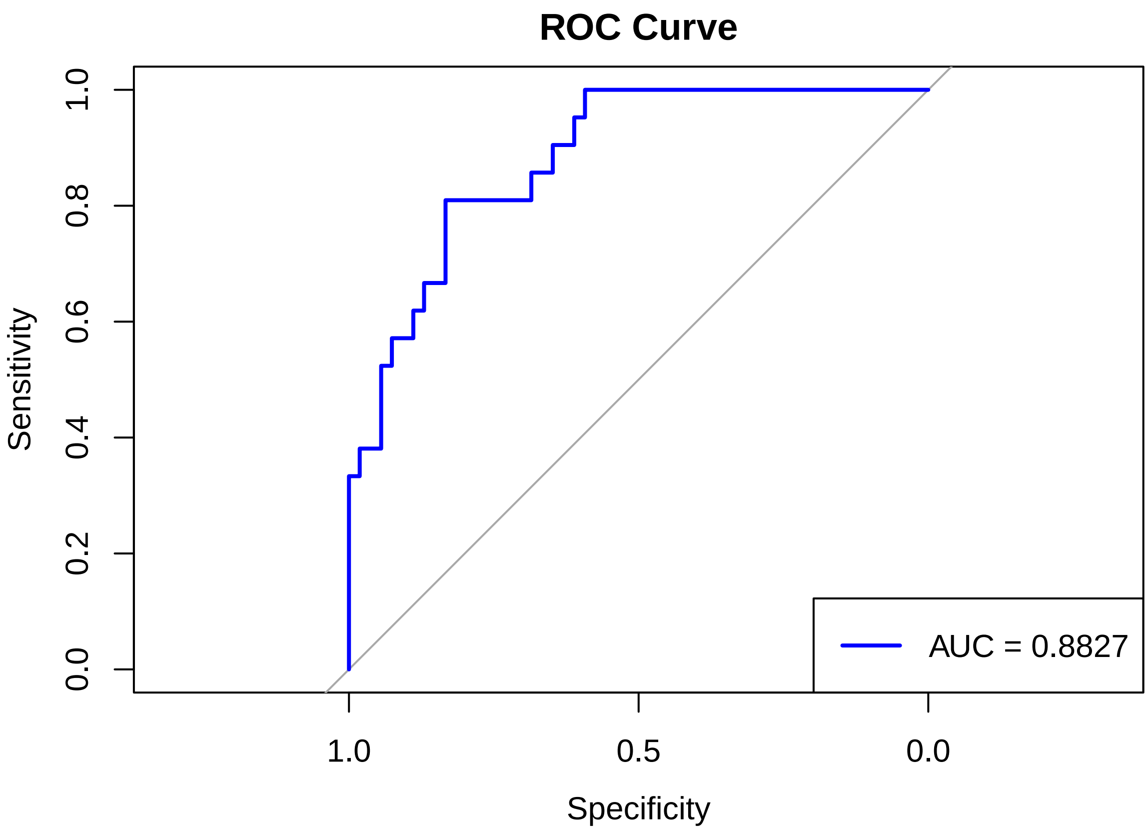
```
## The following objects are masked from 'package:stats':
##
##     cov, smooth, var
```

```
# Create ROC curve
roc_curve <- roc(test_data$DEATH_EVENT, pred_prob)
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
# Plot ROC curve
plot(roc_curve, main = "ROC Curve", col = "blue", lwd = 2)

# Add a legend
legend("bottomright", legend = paste("AUC =", round(auc(roc_curve), 4)), col = "blue", lwd = 2)
```



Again AUC score is 0.8843 which represent good measure of the discriminative ability of a classification model.