

Survival Analysis of Post-Myocardial Infarction Patients

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Abstract

Background

The rates of myocardial infarction is becoming an increasing common occurrence in the United States. As medical knowledge and techniques improve to meet need of infarction episode, so does the need to understand the survivability of patients who have survived such episodes.

Objectives

Our goal is to provide detailed survival statistics of post-myocardial infarction patients as well as provide an accurate regression model to best prediction of survival outcomes of a single year following an infarction episode.

Methods

Data from 133 post-myocardial infarction patients measure the time in months until death in a one year monitoring period of follow-up. We use a combination of nonparametric (Kaplan-Meier) and parametric methods (Weibull/Cox PH) to determine estimates of survival among gender and myocardial strata (contraction depth, muscular activity,). We consider a slew of statistical and graphical results before determining the most appropriate method of modeling.

Results

Out of all of our methods, we have determined that \square is the most appropriate model for prediction of patient survival. We have AIC values of . We have BIC values. Thus, this model is the best.

Conclusion

[summary statistics] [review of our model + specific survival rates]

Introduction

Heart disease has become the leader cause of death among the US population among a majority of all racial and ethnic groups (Heron 2019). Myocardial infarctions are becoming largely common among U.S. populations. The number of myocardial infarctions are remarkably increased from [start date] to [end date] by [x] amount (add citation). In 2015, approximately 23% of all fatalities in the United States was related to some degree of heart disease (cdc. cite please). Unsurprisingly, clinical studies have shown harmful symptoms in post-infarction survival patients. Our obtained dataset to examine the tangible difference in survivability rates from the course of year following an infarction episode.

Table 1: Dataset Variable Labels

| Variable | Label | Definition |
|--|--------------|---|
| Survival | Survival | The number of months the patients survived, post-myocardial infarction |
| Status | Status | Censorship status. 0 denotes that a patient is a censored while |
| Alive at the end of Survival Period | Alive.E | Binary variable. 0 denotes that patient is alive at the end of the |
| Patient Age | Age | The age in years when a myocardial infarction occurs. |
| Age Group | Age.Strata | 0 denotes 49 or younger. 1 denotes 50 or older. 2 denotes 65 or older |
| Pericardial Effusion | P.Effusion | Binary variable. Pericardial effusion is excess fluid surrounding the heart |
| Fractional Shortening | F.Shortening | Fractional shortening is a measure of contractility around the heart |
| E-Point Septal Separation | EPSS | E-point septal separation is an additional measure of heart contractility |
| Left Ventricular End-Diastolic Dimension | LVDD | Left ventricular end-diastolic dimension is the measure of the left ventricle |
| Wall Motion Score | WMS | Wall motion score is a measure of how the segments of the left ventricle |
| Wall Motion Index | WMI | Wall motion index is the wall motion score divided by the number of segments |

By applying survival analysis techniques to this data set, we seek to achieve improved understanding of the characteristics exhibited by patients in a one year post-infarction interval. We also propose a model to better predict the probability of a survival of patients based on these variable characteristics.

Dataset

We have obtained our data set from Kaggle. The data set contains 131 observations and records 8 variables. It should be noted that two patients data were removed as there was no recorded months survival date.

Below is a table summary of each table header variable label and a definition of that variable.

Since the time of infarction varies, some patients were followed for less than a year. This provides a clear censoring and truncation provide. We will address this concern in detail in the later in this section. It should be noted that we have a slew of missing values. Since a single patient has shown as missing, we have opted to impute the values for this data row. With this in mind, our predictive and summary models will have less than ideal accuracy.

The full dataset is available in the appendix of this paper.

Methodology

Censoring

Right censored: this study has a fixed start and end date. Some patients start the study midway through the study and thus, we cannot measure the total little length.

Imputation

There are several missing values in the data set. The variables we chose to more ## Summary statistics Over the course of the study, there is a ## Kaplan-Meier We conduct nonparametric Kaplan-Meier fit on our data over multiple strata. We first conduct a fit over all patients in regards to censoring. Then we work on gender groups, age, and general ventricular condition. A survival function can be defined as:

[insert latex equation for survival function, with censored values]

Weibull Fits (+Cox PH)

Log-Normal

Results

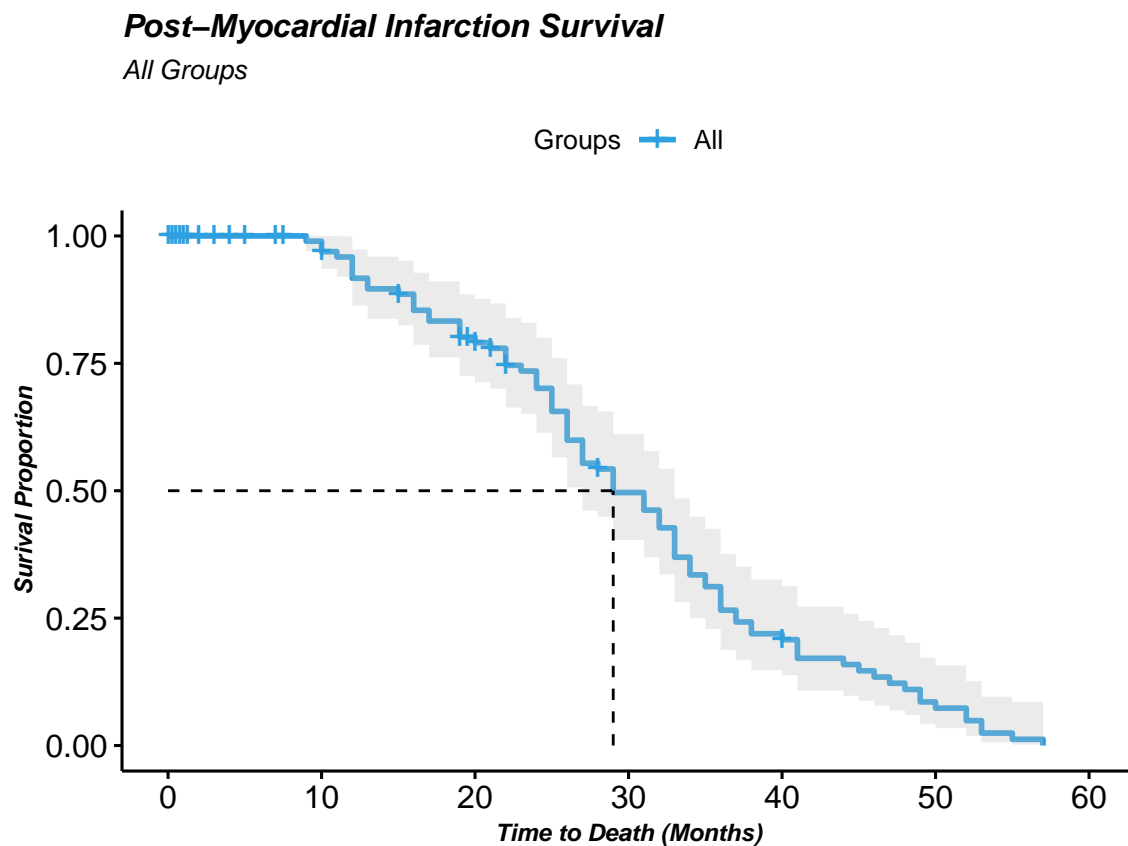
Table of Summary Statistics

| ## | speed | dist |
|----|--------------|----------------|
| ## | Min. : 4.0 | Min. : 2.00 |
| ## | 1st Qu.:12.0 | 1st Qu.: 26.00 |
| ## | Median :15.0 | Median : 36.00 |
| ## | Mean :15.4 | Mean : 42.98 |
| ## | 3rd Qu.:19.0 | 3rd Qu.: 56.00 |
| ## | Max. :25.0 | Max. :120.00 |

KM Curve & Hazard

Survival Curves

KM Overall

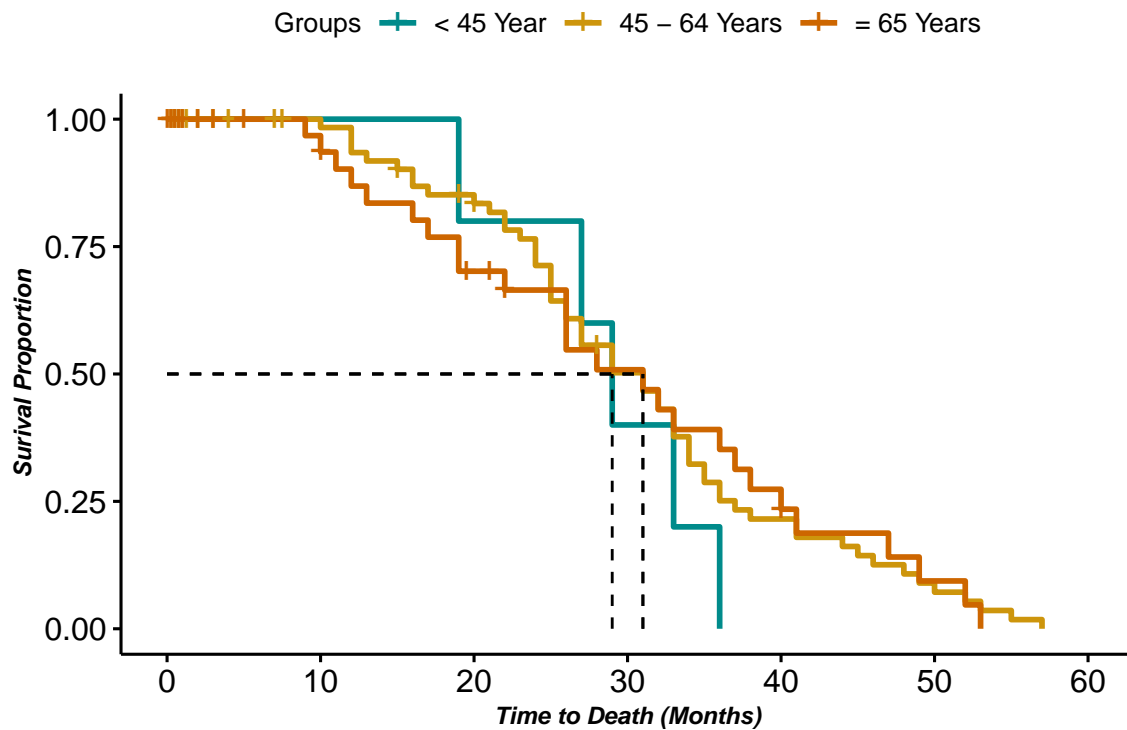


Here is the survival curve for all groups within our dataset. We see that a majority of our censored values have very short survival times. This is very intuitive given to our limited interval study time of a single year. We clearly see a median survival time of approximately 29 weeks.

KM Age

Post-Myocardial Infarction Survival

Stratified by Age Group

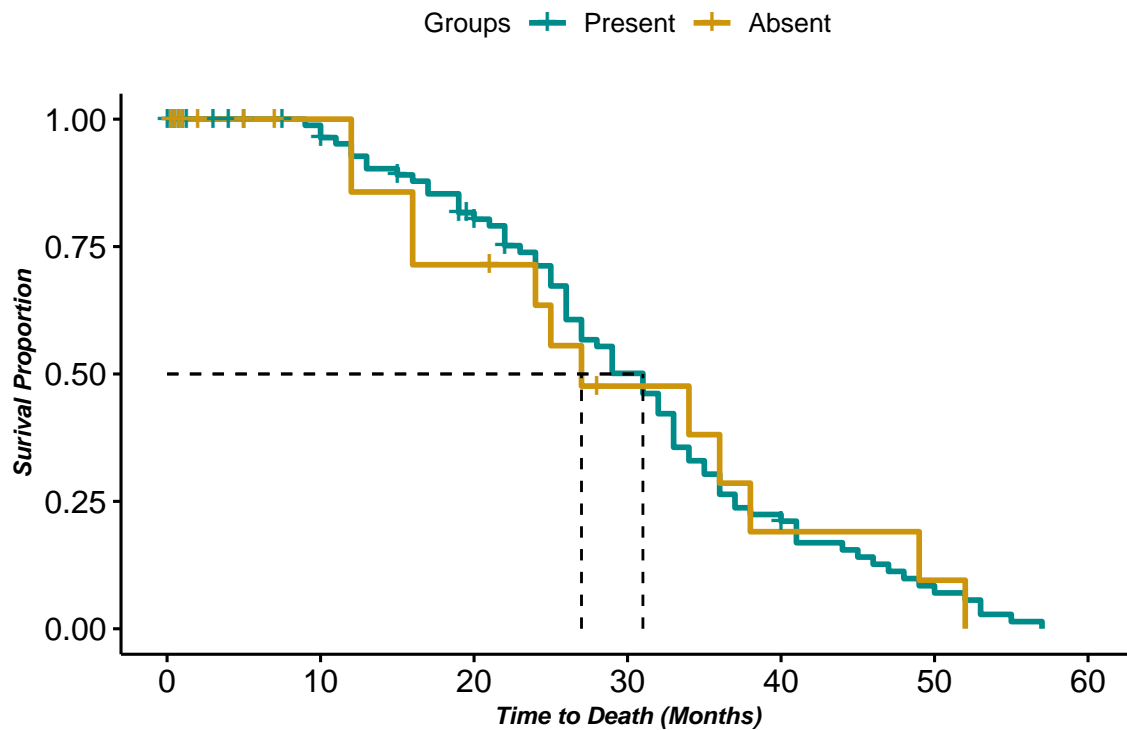


Brief fitting of stratification survival by age shows some surviving results. The youngest group has the highest survival to the median, and then see a sharp decrease in survivability after the median time of 30 months has past. In contrast, our two older groups have relatively similar patterns of survivability through the median. Given that younger individuals generally have healthier hearts, patients that experience a myocardial infarction at a younger age are likely to have a slew of other complication conditions.

KM P.Effusion

Post-Myocardial Infarction Survival

Stratified by Presence of Pericardial Effusion



KM Ventricular Activity

```
##      speed      dist
##  Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean   : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.   :120.00
```

Hazard Plots

Weibull Curve

```
##      speed      dist
##  Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean   : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.   :120.00
```

Cox Proportional Hazard

```
##      speed      dist
##  Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
```

```
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean    : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.    :120.00
```

Model Diagnostics

AIC, BIC, and Confidence Intervals

```
##      speed      dist
## Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean    : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.    :120.00
```

Residual Analysis/QQ Plot

```
##      speed      dist
## Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean    : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.    :120.00
```

```
##      speed      dist
## Min.   : 4.0    Min.   : 2.00
## 1st Qu.:12.0    1st Qu.: 26.00
## Median :15.0    Median : 36.00
## Mean   :15.4    Mean    : 42.98
## 3rd Qu.:19.0    3rd Qu.: 56.00
## Max.   :25.0    Max.    :120.00
```

Discussion

References

- Heron, M. Deaths: Leading causes for 2017 pdf icon[PDF – 3 M]. National Vital Statistics Reports;68(6). Accessed November 19, 2019.
- Salzberg, S. (1988). Exemplar-based learning: Theory and implementation (Technical Report TR-10-88). Harvard University, Center for Research in Computing Technology, Aiken Computation Laboratory (33 Oxford Street; Cambridge, MA 02138).
- Kan, G., Visser, C., Kooler, J., & Dunning, A. (1986). Short and long term predictive value of wall motion score in acute myocardial infarction. *British Heart Journal*, 56, 422-427.
- Fryar CD, Chen T-C, Li X. Prevalence of uncontrolled risk factors for cardiovascular disease: United States, 1999–2010 pdf icon[PDF-494K]. NCHS data brief, no. 103. Hyattsville, MD: National Center for Health Statistics; 2012. Accessed May 9, 2019.

Appendix

Dataset

R Code

Table 2: Dataset

| Survival | Status | Alive.E | Age | Age.Strata | P.Effusion | F.Shortening | EPSS | LVDD |
|----------|--------|---------|-------|------------|------------|-----------------------|--------------------|----------|
| 11.00 | 1 | 0 | 71 | 2 | 0 | 0.26 | 9 | 4.599999 |
| 19.00 | 1 | 0 | 72 | 2 | 0 | 0.38 | 6 | 4.099999 |
| 16.00 | 1 | 0 | 55 | 1 | 0 | 0.26 | 4 | 3.42 |
| 57.00 | 1 | 0 | 60 | 1 | 0 | 0.253 | 12.061999999999999 | 4.602999 |
| 19.00 | 0 | 1 | 57 | 1 | 0 | 0.16 | 22 | 5.75 |
| 26.00 | 1 | 0 | 68 | 2 | 0 | 0.26 | 5 | 4.309999 |
| 13.00 | 1 | 0 | 62 | 1 | 0 | 0.23 | 31 | 5.43 |
| 50.00 | 1 | 0 | 60 | 1 | 0 | 0.33 | 8 | 5.25 |
| 19.00 | 1 | 0 | 46 | 0 | 0 | 0.34 | 0 | 5.09 |
| 25.00 | 1 | 0 | 54 | 1 | 0 | 0.14000000000000001 | 13 | 4.49 |
| 10.00 | 0 | 1 | 77 | 2 | 0 | 0.13 | 16 | 4.230000 |
| 52.00 | 1 | 0 | 62 | 1 | 1 | 0.45 | 9 | 3.6 |
| 52.00 | 1 | 0 | 73 | 2 | 0 | 0.33 | 6 | 4 |
| 44.00 | 1 | 0 | 60 | 1 | 0 | 0.15 | 10 | 3.73 |
| 0.50 | 0 | 1 | 62 | 1 | 0 | 0.12 | 23 | 5.8 |
| 24.00 | 1 | 0 | 55 | 1 | 1 | 0.25 | 12.063000000000001 | 4.29 |
| 0.50 | 0 | 1 | 69 | 2 | 1 | 0.26 | 11 | 4.650000 |
| 0.50 | 0 | 1 | 62.53 | 1 | 1 | 7.0000000000000007E-2 | 20 | 5.2 |
| 22.00 | 0 | 1 | 66 | 2 | 0 | 0.09 | 17 | 5.819 |
| 1.00 | 0 | 1 | 66 | 2 | 1 | 0.22 | 15 | 5.4 |
| 0.75 | 0 | 1 | 69 | 2 | 0 | 0.15 | 12 | 5.39 |
| 0.75 | 0 | 1 | 85 | 2 | 1 | 0.18 | 19 | 5.46 |
| 0.50 | 0 | 1 | 73 | 2 | 0 | 0.23 | 12.733000000000001 | 6.06 |
| 5.00 | 0 | 1 | 71 | 2 | 0 | 0.17 | 0 | 4.650000 |
| 48.00 | 1 | 0 | 64 | 1 | 0 | 0.19 | 5.9 | 3.48 |
| 29.00 | 1 | 0 | 54 | 1 | 0 | 0.3 | 7 | 3.85 |
| 29.00 | 1 | 0 | 35 | 0 | 0 | 0.3 | 5 | 4.17 |
| 29.00 | 1 | 0 | 55 | 1 | 0 | ? | 7 | ? |
| 0.25 | 0 | 1 | 75 | 2 | 0 | ? | ? | ? |
| 36.00 | 1 | 0 | 55 | 1 | 1 | 0.21 | 4.2 | 4.16 |
| 1.00 | 0 | 1 | 65 | 2 | 0 | 0.15 | ? | 5.05 |
| 1.00 | 0 | 1 | 52 | 1 | 1 | 0.17 | 17.2 | 5.32 |
| 3.00 | 0 | 1 | ? | 2 | 0 | ? | 12 | ? |
| 27.00 | 1 | 0 | 47 | 0 | 0 | 0.4 | 5.12 | 3.1 |
| 35.00 | 1 | 0 | 63 | 1 | 0 | ? | 10 | ? |
| 26.00 | 1 | 0 | 61 | 1 | 0 | 0.61 | 13.1 | 4.07 |
| 16.00 | 1 | 0 | 63 | 1 | 1 | ? | ? | 5.31 |
| 1.00 | 0 | 1 | 65 | 2 | 0 | 0.06 | 23.6 | ? |
| 19.00 | 1 | 0 | 68 | 2 | 0 | 0.51 | ? | 3.88 |
| 31.00 | 1 | 0 | 80 | 2 | 0 | 0.41 | 5.4 | 4.360000 |
| 32.00 | 1 | 0 | 54 | 1 | 0 | 0.35 | 9.3000000000000007 | 3.63 |
| 16.00 | 1 | 0 | 70 | 2 | 1 | 0.27 | 4.7 | 4.49 |
| 40.00 | 1 | 0 | 79 | 2 | 0 | 0.15 | 17.5 | 4.269999 |
| 46.00 | 1 | 0 | 56 | 1 | 0 | 0.33 | ? | 3.59 |
| 2.00 | 0 | 1 | 67 | 2 | 1 | 0.44 | 9 | 3.96 |
| 37.00 | 1 | 0 | 64 | 1 | 0 | 0.09 | ? | ? |
| 19.50 | 0 | 1 | 81 | 2 | 0 | 0.12 | ? | ? |
| 20.00 | 0 | 1 | 59 | 1 | 0 | 0.03 | 21.3 | 6.29 |
| 0.25 | 0 | 1 | 63 | 1 | 1 | ? | ? | ? |
| 2.00 | 0 | 1 | 56 | 1 | 1 | 0.04 | 14 | 5 |
| 7.00 | 0 | 1 | 61 | 1 | 1 | 0.27 | ? | ? |
| 10.00 | 1 | 0 | 57 | 1 | 8 | 0 | 14.8 | 5.26 |
| 12.00 | 1 | 0 | 58 | 1 | 0 | 0.3 | 9.4 | 3.49 |
| 1.00 | 0 | 1 | 60 | 1 | 0 | 0.01 | 24.6 | 5.65 |
| 10.00 | 1 | 0 | 66 | 2 | 0 | 0.28999999999999998 | 15.6 | 6.15 |