Build Survival Model: Cox Proportional Hazards Model

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```
library(tidyverse)
library(survival)
library(forestplot)
library(glmnet)
library(ggfortify)
library(kableExtra) # include knitr automatically

source("/work/users/y/u/yuukias/BIOS-Material/BIOS992/utils/csv_utils.r")
# * Don't use setwd() for Quarto documents!
# setwd("/work/users/y/u/yuukias/BIOS-Material/BIOS992/data")

adjust_type <- ifelse(exists("params"), params$adjust_type, "partial") #
 ↪  options: "minimal", "partial", "full"
```

```
impute_type <- ifelse(exists("params"), params$impute_type, "unimputed") #
 ↪  options: "unimputed", "imputed"
include_statin <- ifelse(exists("params"), params$include_statin, "no") #
 ↪  options: "yes", "no"
```

```
# string of parameters
adjust_type_str <- switch(adjust_type,
    minimal = "minimal",
    partial = "partial",
    full = "full"
)
print(paste0("Model Adjustment Type: ", adjust_type_str))
```

```
[1] "Model Adjustment Type: partial"
```

```
impute_type_str <- switch(impute_type,
    unimputed = "unimputed",
    imputed = "imputed"
)
print(paste0("Data Imputation Type: ", impute_type_str))
```

```
[1] "Data Imputation Type: unimputed"
```

Load Data

```
if (include_statin == "yes") {
    data_train <-
 ↪  read.csv(paste0("/work/users/y/u/yuukias/BIOS-Material/BIOS992/data/train_data_",
 ↪  impute_type_str, "_statin.csv"),
        header = TRUE
    )
} else {
    data_train <-
 ↪  read.csv(paste0("/work/users/y/u/yuukias/BIOS-Material/BIOS992/data/train_data_",
 ↪  impute_type_str, ".csv"),
        header = TRUE
    )
```

```
}

data_train <- data_train[, -1] # the first column is the index generated by
 ↪  sklearn
(dim(data_train))
```

```
[1] 28127   100
```

```
data <- select_subset(data_train, type = adjust_type)
(dim(data))
```

```
[1] 28127    75
```

```
colnames(data)
```

```
 [1] "event"                     "time"
 [3] "HRV_MeanNN"                "HRV_SDNN"
 [5] "HRV_RMSSD"                 "HRV_SDSD"
 [7] "HRV_CVNN"                  "HRV_CVSD"
 [9] "HRV_MedianNN"              "HRV_MadNN"
[11] "HRV_MCVNN"                 "HRV_IQRNN"
[13] "HRV_SDRMSSD"               "HRV_Prc20NN"
[15] "HRV_Prc80NN"               "HRV_pNN50"
[17] "HRV_pNN20"                 "HRV_MinNN"
[19] "HRV_MaxNN"                 "HRV_HTI"
[21] "HRV_TINN"                  "HRV_LF"
[23] "HRV_HF"                    "HRV_VHF"
[25] "HRV_TP"                    "HRV_LFHF"
[27] "HRV_LFn"                   "HRV_HFn"
[29] "HRV_LnHF"                  "HRV_SD1"
[31] "HRV_SD2"                   "HRV_SD1SD2"
[33] "HRV_S"                     "HRV_CSI"
[35] "HRV_CVI"                   "HRV_CSI_Modified"
[37] "HRV_PIP"                   "HRV_IALS"
[39] "HRV_PSS"                   "HRV_PAS"
[41] "HRV_GI"                    "HRV_SI"
[43] "HRV_AI"                    "HRV_PI"
[45] "HRV_C1d"                   "HRV_C1a"
[47] "HRV_SD1d"                  "HRV_SD1a"
```

```
[49] "HRV_C2d"                      "HRV_C2a"
[51] "HRV_SD2d"                     "HRV_SD2a"
[53] "HRV_Cd"                       "HRV_Ca"
[55] "HRV_SDNNd"                    "HRV_SDNNa"
[57] "HRV_ApEn"                     "HRV_ShanEn"
[59] "HRV_FuzzyEn"                  "HRV_MSEn"
[61] "HRV_CMSEn"                    "HRV_RCMSEn"
[63] "HRV_CD"                       "HRV_HFD"
[65] "HRV_KFD"                      "HRV_LZC"
[67] "HRV_DFA_alpha1"               "HRV_MFDFA_alpha1_Width"
[69] "HRV_MFDFA_alpha1_Peak"        "HRV_MFDFA_alpha1_Mean"
[71] "HRV_MFDFA_alpha1_Max"         "HRV_MFDFA_alpha1_Delta"
[73] "HRV_MFDFA_alpha1_Asymmetry"   "HRV_MFDFA_alpha1_Fluctuation"
[75] "HRV_MFDFA_alpha1_Increment"
```

```r
data <- tibble::as_tibble(data)
```

```r
# * It is very hard to compare the HR as different predictors are on
 ↪  different magnitudes, so we need to normalize them.
time_col <- data$time
event_col <- data$event
data <- data %>%
    select(-c(time, event)) %>%
    mutate(across(where(is.numeric), scale)) %>%
    mutate(
        time = time_col,
        event = event_col
    )
```

Note now the interpretation of HR is different! For example, if HR=1.16 for the predictor in the univariate model fitted using scaled data, it means that each standard deviation increase is associated with 16% higher risk of event.

```r
data_complete <- na.omit(data)
```

Univariate Cox Proportional Hazards Model

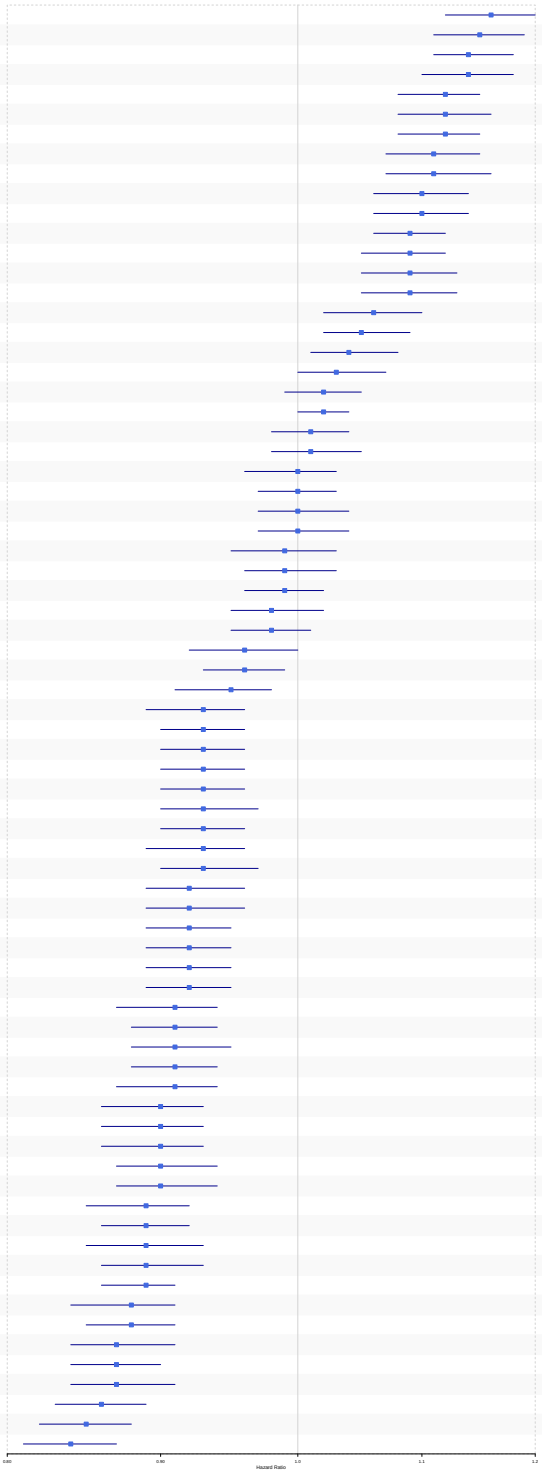
```r
if (!("time" %in% colnames(data) && "event" %in% colnames(data))) {
    stop("time and event columns are required")
}
predictors <- colnames(data)[!colnames(data) %in% c("time", "event")]

results_univariate <- map_dfr(predictors, function(predictor) {
    formula <- as.formula(paste("Surv(time, event) ~", predictor))
    # cox_model_single <- coxph(Surv(time, event) ~ get(predictor), data =
    ↪  data)  # equivalent way
    cox_model_single <- coxph(formula, data = data)

    coef <- coef(cox_model_single) # log hazard ratio
    se <- sqrt(diag(vcov(cox_model_single)))

    hr <- exp(coef)
    lower_ci <- exp(coef - 1.96 * se)
    upper_ci <- exp(coef + 1.96 * se)
    p_value <- summary(cox_model_single)$coefficients[5]

    return(
        data.frame(
            predictor = predictor,
            hr = hr,
            lower_ci = lower_ci,
            upper_ci = upper_ci,
            p_value = p_value
        )
    )
})
results_univariate$hr <- round(results_univariate$hr, 2)
results_univariate$lower_ci <- round(results_univariate$lower_ci, 2)
results_univariate$upper_ci <- round(results_univariate$upper_ci, 2)
results_univariate$ci <- paste0("(", results_univariate$lower_ci, ",",
↪  results_univariate$upper_ci, ")")
results_univariate$p_value <- round(results_univariate$p_value, 3)
results_univariate <- results_univariate %>% arrange(desc(hr)) # sort
↪  descendingly by HR
```

```r
# Create forest plot
results_univariate %>%
    forestplot(
```

```
        labeltext = c(predictor, hr, ci, p_value),
        mean = hr,
        lower = lower_ci,
        upper = upper_ci,
        xlab = "Hazard Ratio",
        title = "Univariate Cox Models",
        xlog = TRUE, # * Make sure the CI are not symmetric and need to be
         ↪  transformed
        boxsize = 0.2,
        xticks = c(0.8, 0.9, 1.0, 1.1, 1.2),
        clip = c(0.8, 1.2),
        zero = 1
    ) %>%
    fp_set_style(
        box = "royalblue",
        line = "darkblue",
        summary = "royalblue"
    ) %>%
    fp_add_header(
        predictor = c("Predictor", ""),
        hr = c("Hazard Ratio", "per SD increase"),
        ci = c("95% CI", ""),
        p_value = c("p-value", "")
    ) %>%
    fp_decorate_graph(
        box = gpar(lty = 2, col = "lightgray"),
        graph.pos = 4
    ) %>% # change the position of forest plot
    fp_set_zebra_style("#f9f9f9")
```

Univariate Cox Models

Predictor	Hazard Ratio per SD increase	95% CI	p−value
HRV_PIP	1.16	(1.12,1.2)	0
HRV_IALS	1.15	(1.11,1.19)	0
HRV_SD1SD2	1.14	(1.11,1.18)	0
HRV_HFD	1.14	(1.1,1.18)	0
HRV_PAS	1.12	(1.08,1.15)	0
HRV_GI	1.12	(1.08,1.16)	0
HRV_SI	1.12	(1.08,1.15)	0
HRV_PSS	1.11	(1.07,1.15)	0
HRV_AI	1.11	(1.07,1.16)	0
HRV_ApEn	1.1	(1.06,1.14)	0
HRV_CMSEn	1.1	(1.06,1.14)	0
HRV_VHF	1.09	(1.06,1.12)	0
HRV_C2d	1.09	(1.05,1.12)	0
HRV_Cd	1.09	(1.05,1.13)	0
HRV_RCMSEn	1.09	(1.05,1.13)	0
HRV_C1d	1.06	(1.02,1.1)	0.001
HRV_pNN20	1.05	(1.02,1.09)	0.003
HRV_MFDFA_alpha1_Asymmetry	1.04	(1.01,1.08)	0.012
HRV_MSEn	1.03	(1,1.07)	0.075
HRV_pNN50	1.02	(0.99,1.05)	0.281
HRV_KFD	1.02	(1,1.04)	0.05
HRV_ShanEn	1.01	(0.98,1.04)	0.621
HRV_MFDFA_alpha1_Width	1.01	(0.98,1.05)	0.429
HRV_HF	1	(0.96,1.03)	0.845
HRV_TP	1	(0.97,1.03)	0.984
HRV_MFDFA_alpha1_Fluctuation	1	(0.97,1.04)	0.914
HRV_MFDFA_alpha1_Increment	1	(0.97,1.04)	0.788
HRV_LFHF	0.99	(0.95,1.03)	0.611
HRV_HFn	0.99	(0.96,1.03)	0.719
HRV_LnHF	0.99	(0.96,1.02)	0.598
HRV_S	0.98	(0.95,1.02)	0.301
HRV_MFDFA_alpha1_Mean	0.98	(0.95,1.01)	0.181
HRV_TINN	0.96	(0.92,1)	0.028
HRV_FuzzyEn	0.96	(0.93,0.99)	0.011
HRV_C1a	0.95	(0.91,0.98)	0.001
HRV_SDSD	0.93	(0.89,0.96)	0
HRV_CVSD	0.93	(0.9,0.96)	0
HRV_MadNN	0.93	(0.9,0.96)	0
HRV_MCVNN	0.93	(0.9,0.96)	0
HRV_IQRNN	0.93	(0.9,0.96)	0
HRV_HTI	0.93	(0.9,0.97)	0
HRV_LF	0.93	(0.9,0.96)	0
HRV_SD1	0.93	(0.89,0.96)	0
HRV_SD1d	0.93	(0.9,0.97)	0
HRV_RMSSD	0.92	(0.89,0.96)	0
HRV_SD1a	0.92	(0.89,0.96)	0
HRV_C2a	0.92	(0.89,0.95)	0
HRV_Ca	0.92	(0.89,0.95)	0
HRV_MFDFA_alpha1_Max	0.92	(0.89,0.95)	0
HRV_MFDFA_alpha1_Delta	0.92	(0.89,0.95)	0
HRV_SDNN	0.91	(0.87,0.94)	0
HRV_PI	0.91	(0.88,0.94)	0
HRV_SDNNd	0.91	(0.88,0.95)	0
HRV_CD	0.91	(0.88,0.94)	0
HRV_MFDFA_alpha1_Peak	0.91	(0.87,0.94)	0
HRV_MedianNN	0.9	(0.86,0.93)	0
HRV_Prc80NN	0.9	(0.86,0.93)	0
HRV_SD2	0.9	(0.86,0.93)	0
HRV_SD2d	0.9	(0.87,0.94)	0
HRV_SDNNa	0.9	(0.87,0.94)	0
HRV_MeanNN	0.89	(0.85,0.92)	0
HRV_LFn	0.89	(0.86,0.92)	0
HRV_CSI_Modified	0.89	(0.85,0.93)	0
HRV_SD2a	0.89	(0.86,0.93)	0
HRV_LZC	0.89	(0.86,0.91)	0
HRV_CVNN	0.88	(0.84,0.91)	0
HRV_DFA_alpha1	0.88	(0.85,0.91)	0
HRV_Prc20NN	0.87	(0.84,0.91)	0
HRV_MinNN	0.87	(0.84,0.9)	0
HRV_MaxNN	0.87	(0.84,0.91)	0
HRV_CVI	0.86	(0.83,0.89)	0
HRV_CSI	0.85	(0.82,0.88)	0
HRV_SDRMSSD	0.84	(0.81,0.87)	0



Multivariate Cox Proportional Hazards Model

```
cox_model_full <- coxph(Surv(time, event) ~ ., data = data)
summary(cox_model_full)
```

```
Call:
coxph(formula = Surv(time, event) ~ ., data = data)

  n= 26782, number of events= 3386
   (1345 observations deleted due to missingness)

                              coef  exp(coef)   se(coef)      z Pr(>|z|)
HRV_MeanNN                3.147e-01  1.370e+00  5.602e-01  0.562 0.574235
HRV_SDNN                  3.476e-01  1.416e+00  1.284e+00  0.271 0.786618
HRV_RMSSD                 2.283e+01  8.208e+09  1.222e+01  1.868 0.061703
HRV_SDSD                 -2.192e+01  3.029e-10  1.191e+01 -1.840 0.065817
HRV_CVNN                 -1.601e-01  8.521e-01  3.740e-01 -0.428 0.668581
HRV_CVSD                  2.127e-01  1.237e+00  2.921e-01  0.728 0.466575
HRV_MedianNN             -1.061e-01  8.993e-01  1.765e-01 -0.601 0.547740
HRV_MadNN                 4.062e-01  1.501e+00  2.034e-01  1.997 0.045861
HRV_MCVNN                -2.747e-01  7.598e-01  9.696e-02 -2.833 0.004606
HRV_IQRNN                 1.032e-01  1.109e+00  1.066e-01  0.969 0.332552
HRV_SDRMSSD               1.127e-01  1.119e+00  3.386e-01  0.333 0.739232
HRV_Prc20NN              -1.788e-01  8.363e-01  9.391e-02 -1.904 0.056963
HRV_Prc80NN              -9.794e-02  9.067e-01  1.651e-01 -0.593 0.553129
HRV_pNN50                 5.323e-02  1.055e+00  3.386e-02  1.572 0.116010
HRV_pNN20                -2.237e-02  9.779e-01  4.396e-02 -0.509 0.610803
HRV_MinNN                -2.624e-02  9.741e-01  3.499e-02 -0.750 0.453360
HRV_MaxNN                -3.356e-01  7.149e-01  1.582e-01 -2.122 0.033836
HRV_HTI                   1.382e-01  1.148e+00  3.375e-02  4.096 4.21e-05
HRV_TINN                  5.296e-02  1.054e+00  3.659e-02  1.447 0.147826
HRV_LF                   -6.691e-02  9.353e-01  4.589e-02 -1.458 0.144885
HRV_HF                    4.940e-03  1.005e+00  4.956e-02  0.100 0.920609
HRV_VHF                   1.036e-02  1.010e+00  3.911e-02  0.265 0.791129
HRV_TP                           NA         NA  0.000e+00     NA       NA
HRV_LFHF                 -1.399e-01  8.694e-01  1.668e-01 -0.839 0.401612
HRV_LFn                   1.409e-01  1.151e+00  7.710e-02  1.828 0.067528
HRV_HFn                   1.372e-02  1.014e+00  5.882e-02  0.233 0.815594
HRV_LnHF                  2.567e-02  1.026e+00  8.534e-02  0.301 0.763546
HRV_SD1                          NA         NA  0.000e+00     NA       NA
HRV_SD2                   9.793e-01  2.662e+00  1.434e+00  0.683 0.494791
```

HRV_SD1SD2	-1.273e-03	9.987e-01	1.039e-01	-0.012	0.990229
HRV_S	-1.826e-01	8.331e-01	3.846e-01	-0.475	0.634995
HRV_CSI	-3.395e-02	9.666e-01	3.624e-01	-0.094	0.925366
HRV_CVI	-3.893e-01	6.776e-01	2.913e-01	-1.336	0.181442
HRV_CSI_Modified	-2.784e-01	7.570e-01	4.832e-01	-0.576	0.564450
HRV_PIP	6.460e-01	1.908e+00	3.166e-01	2.040	0.041302
HRV_IALS	-5.386e-01	5.836e-01	2.972e-01	-1.812	0.070005
HRV_PSS	4.236e-03	1.004e+00	3.692e-02	0.115	0.908671
HRV_PAS	5.749e-03	1.006e+00	2.968e-02	0.194	0.846402
HRV_GI	2.453e-01	1.278e+00	1.897e-01	1.293	0.195844
HRV_SI	-4.342e-02	9.575e-01	7.746e-02	-0.561	0.575095
HRV_AI	-1.028e-01	9.023e-01	2.053e-01	-0.501	0.616413
HRV_PI	-7.616e-02	9.267e-01	3.205e-02	-2.377	0.017473
HRV_C1d	-7.610e-02	9.267e-01	8.358e-02	-0.910	0.362577
HRV_C1a	NA	NA	0.000e+00	NA	NA
HRV_SD1d	2.019e-02	1.020e+00	1.078e+00	0.019	0.985052
HRV_SD1a	-1.164e+00	3.123e-01	1.511e+00	-0.770	0.441346
HRV_C2d	3.550e-02	1.036e+00	7.980e-02	0.445	0.656403
HRV_C2a	NA	NA	0.000e+00	NA	NA
HRV_SD2d	2.966e-01	1.345e+00	1.341e+00	0.221	0.824942
HRV_SD2a	-5.340e-01	5.863e-01	1.584e+00	-0.337	0.735967
HRV_Cd	-4.800e-02	9.531e-01	1.021e-01	-0.470	0.638369
HRV_Ca	NA	NA	0.000e+00	NA	NA
HRV_SDNNd	-6.519e-01	5.211e-01	2.085e+00	-0.313	0.754567
HRV_SDNNa	5.203e-01	1.683e+00	2.689e+00	0.193	0.846575
HRV_ApEn	1.165e-01	1.124e+00	3.524e-02	3.305	0.000949
HRV_ShanEn	-3.011e-03	9.970e-01	4.120e-02	-0.073	0.941729
HRV_FuzzyEn	-5.086e-02	9.504e-01	4.969e-02	-1.024	0.306065
HRV_MSEn	-1.069e-02	9.894e-01	3.015e-02	-0.354	0.722996
HRV_CMSEn	-5.603e-02	9.455e-01	7.241e-02	-0.774	0.439012
HRV_RCMSEn	1.508e-01	1.163e+00	6.759e-02	2.232	0.025638
HRV_CD	-2.574e-01	7.730e-01	3.831e-02	-6.719	1.83e-11
HRV_HFD	2.730e-02	1.028e+00	4.532e-02	0.602	0.546971
HRV_KFD	7.953e-03	1.008e+00	1.061e-02	0.750	0.453513
HRV_LZC	-4.114e-02	9.597e-01	3.008e-02	-1.367	0.171483
HRV_DFA_alpha1	-2.706e-02	9.733e-01	7.796e-02	-0.347	0.728526
HRV_MFDFA_alpha1_Width	-1.548e-01	8.566e-01	1.680e-01	-0.921	0.357000
HRV_MFDFA_alpha1_Peak	-4.803e-02	9.531e-01	4.875e-02	-0.985	0.324504
HRV_MFDFA_alpha1_Mean	1.247e-01	1.133e+00	1.699e-01	0.734	0.462980
HRV_MFDFA_alpha1_Max	-1.133e-01	8.929e-01	1.031e-01	-1.099	0.271850
HRV_MFDFA_alpha1_Delta	6.368e-02	1.066e+00	1.068e-01	0.596	0.551053
HRV_MFDFA_alpha1_Asymmetry	-2.946e-02	9.710e-01	3.235e-02	-0.911	0.362437
HRV_MFDFA_alpha1_Fluctuation	3.577e-02	1.036e+00	1.652e-01	0.216	0.828613

```
HRV_MFDFA_alpha1_Increment    9.848e-03  1.010e+00  2.126e-01  0.046 0.963050

HRV_MeanNN
HRV_SDNN
HRV_RMSSD                   .
HRV_SDSD                    .
HRV_CVNN
HRV_CVSD
HRV_MedianNN
HRV_MadNN                   *
HRV_MCVNN                   **
HRV_IQRNN
HRV_SDRMSSD
HRV_Prc20NN                 .
HRV_Prc80NN
HRV_pNN50
HRV_pNN20
HRV_MinNN
HRV_MaxNN                   *
HRV_HTI                     ***
HRV_TINN
HRV_LF
HRV_HF
HRV_VHF
HRV_TP
HRV_LFHF
HRV_LFn                     .
HRV_HFn
HRV_LnHF
HRV_SD1
HRV_SD2
HRV_SD1SD2
HRV_S
HRV_CSI
HRV_CVI
HRV_CSI_Modified
HRV_PIP                     *
HRV_IALS                    .
HRV_PSS
HRV_PAS
HRV_GI
HRV_SI
HRV_AI
```

```
HRV_PI                          *
HRV_C1d
HRV_C1a
HRV_SD1d
HRV_SD1a
HRV_C2d
HRV_C2a
HRV_SD2d
HRV_SD2a
HRV_Cd
HRV_Ca
HRV_SDNNd
HRV_SDNNa
HRV_ApEn                        ***
HRV_ShanEn
HRV_FuzzyEn
HRV_MSEn
HRV_CMSEn
HRV_RCMSEn                      *
HRV_CD                          ***
HRV_HFD
HRV_KFD
HRV_LZC
HRV_DFA_alpha1
HRV_MFDFA_alpha1_Width
HRV_MFDFA_alpha1_Peak
HRV_MFDFA_alpha1_Mean
HRV_MFDFA_alpha1_Max
HRV_MFDFA_alpha1_Delta
HRV_MFDFA_alpha1_Asymmetry
HRV_MFDFA_alpha1_Fluctuation
HRV_MFDFA_alpha1_Increment
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

                            exp(coef) exp(-coef) lower .95 upper .95
HRV_MeanNN                  1.370e+00  7.300e-01 4.569e-01 4.107e+00
HRV_SDNN                    1.416e+00  7.064e-01 1.143e-01 1.754e+01
HRV_RMSSD                   8.208e+09  1.218e-10 3.268e-01 2.062e+20
HRV_SDSD                    3.029e-10  3.302e+09 2.188e-20 4.192e+00
HRV_CVNN                    8.521e-01  1.174e+00 4.094e-01 1.773e+00
HRV_CVSD                    1.237e+00  8.084e-01 6.978e-01 2.193e+00
HRV_MedianNN                8.993e-01  1.112e+00 6.364e-01 1.271e+00
```

HRV_MadNN	1.501e+00	6.662e-01	1.007e+00	2.236e+00
HRV_MCVNN	7.598e-01	1.316e+00	6.283e-01	9.188e-01
HRV_IQRNN	1.109e+00	9.019e-01	8.998e-01	1.366e+00
HRV_SDRMSSD	1.119e+00	8.934e-01	5.764e-01	2.174e+00
HRV_Prc20NN	8.363e-01	1.196e+00	6.957e-01	1.005e+00
HRV_Prc80NN	9.067e-01	1.103e+00	6.560e-01	1.253e+00
HRV_pNN50	1.055e+00	9.482e-01	9.869e-01	1.127e+00
HRV_pNN20	9.779e-01	1.023e+00	8.972e-01	1.066e+00
HRV_MinNN	9.741e-01	1.027e+00	9.095e-01	1.043e+00
HRV_MaxNN	7.149e-01	1.399e+00	5.243e-01	9.747e-01
HRV_HTI	1.148e+00	8.709e-01	1.075e+00	1.227e+00
HRV_TINN	1.054e+00	9.484e-01	9.814e-01	1.133e+00
HRV_LF	9.353e-01	1.069e+00	8.548e-01	1.023e+00
HRV_HF	1.005e+00	9.951e-01	9.119e-01	1.107e+00
HRV_VHF	1.010e+00	9.897e-01	9.359e-01	1.091e+00
HRV_TP	NA	NA	NA	NA
HRV_LFHF	8.694e-01	1.150e+00	6.270e-01	1.206e+00
HRV_LFn	1.151e+00	8.685e-01	9.899e-01	1.339e+00
HRV_HFn	1.014e+00	9.864e-01	9.034e-01	1.138e+00
HRV_LnHF	1.026e+00	9.747e-01	8.680e-01	1.213e+00
HRV_SD1	NA	NA	NA	NA
HRV_SD2	2.662e+00	3.756e-01	1.601e-01	4.428e+01
HRV_SD1SD2	9.987e-01	1.001e+00	8.147e-01	1.224e+00
HRV_S	8.331e-01	1.200e+00	3.920e-01	1.771e+00
HRV_CSI	9.666e-01	1.035e+00	4.751e-01	1.967e+00
HRV_CVI	6.776e-01	1.476e+00	3.828e-01	1.199e+00
HRV_CSI_Modified	7.570e-01	1.321e+00	2.936e-01	1.951e+00
HRV_PIP	1.908e+00	5.241e-01	1.026e+00	3.549e+00
HRV_IALS	5.836e-01	1.714e+00	3.259e-01	1.045e+00
HRV_PSS	1.004e+00	9.958e-01	9.341e-01	1.080e+00
HRV_PAS	1.006e+00	9.943e-01	9.489e-01	1.066e+00
HRV_GI	1.278e+00	7.825e-01	8.813e-01	1.853e+00
HRV_SI	9.575e-01	1.044e+00	8.226e-01	1.114e+00
HRV_AI	9.023e-01	1.108e+00	6.034e-01	1.349e+00
HRV_PI	9.267e-01	1.079e+00	8.703e-01	9.867e-01
HRV_C1d	9.267e-01	1.079e+00	7.867e-01	1.092e+00
HRV_C1a	NA	NA	NA	NA
HRV_SD1d	1.020e+00	9.800e-01	1.235e-01	8.432e+00
HRV_SD1a	3.123e-01	3.202e+00	1.615e-02	6.042e+00
HRV_C2d	1.036e+00	9.651e-01	8.861e-01	1.212e+00
HRV_C2a	NA	NA	NA	NA
HRV_SD2d	1.345e+00	7.433e-01	9.713e-02	1.863e+01
HRV_SD2a	5.863e-01	1.706e+00	2.631e-02	1.306e+01

```
HRV_Cd                          9.531e-01  1.049e+00 7.802e-01 1.164e+00
HRV_Ca                                 NA         NA        NA        NA
HRV_SDNNd                       5.211e-01  1.919e+00 8.750e-03 3.103e+01
HRV_SDNNa                       1.683e+00  5.943e-01 8.650e-03 3.273e+02
HRV_ApEn                        1.124e+00  8.901e-01 1.049e+00 1.204e+00
HRV_ShanEn                      9.970e-01  1.003e+00 9.197e-01 1.081e+00
HRV_FuzzyEn                     9.504e-01  1.052e+00 8.622e-01 1.048e+00
HRV_MSEn                        9.894e-01  1.011e+00 9.326e-01 1.050e+00
HRV_CMSEn                       9.455e-01  1.058e+00 8.204e-01 1.090e+00
HRV_RCMSEn                      1.163e+00  8.600e-01 1.019e+00 1.327e+00
HRV_CD                          7.730e-01  1.294e+00 7.171e-01 8.333e-01
HRV_HFD                         1.028e+00  9.731e-01 9.403e-01 1.123e+00
HRV_KFD                         1.008e+00  9.921e-01 9.872e-01 1.029e+00
HRV_LZC                         9.597e-01  1.042e+00 9.047e-01 1.018e+00
HRV_DFA_alpha1                  9.733e-01  1.027e+00 8.354e-01 1.134e+00
HRV_MFDFA_alpha1_Width          8.566e-01  1.167e+00 6.162e-01 1.191e+00
HRV_MFDFA_alpha1_Peak           9.531e-01  1.049e+00 8.662e-01 1.049e+00
HRV_MFDFA_alpha1_Mean           1.133e+00  8.827e-01 8.119e-01 1.581e+00
HRV_MFDFA_alpha1_Max            8.929e-01  1.120e+00 7.295e-01 1.093e+00
HRV_MFDFA_alpha1_Delta          1.066e+00  9.383e-01 8.644e-01 1.314e+00
HRV_MFDFA_alpha1_Asymmetry      9.710e-01  1.030e+00 9.113e-01 1.035e+00
HRV_MFDFA_alpha1_Fluctuation    1.036e+00  9.649e-01 7.497e-01 1.433e+00
HRV_MFDFA_alpha1_Increment      1.010e+00  9.902e-01 6.658e-01 1.532e+00

Concordance= 0.59  (se = 0.005 )
Likelihood ratio test= 338.6  on 68 df,   p=<2e-16
Wald test            = 323.5  on 68 df,   p=<2e-16
Score (logrank) test = 327.3  on 68 df,   p=<2e-16
```

```r
cox_model_full_complete <- coxph(Surv(time, event) ~ ., data = data_complete)
summary(cox_model_full_complete)
```

```
Call:
coxph(formula = Surv(time, event) ~ ., data = data_complete)

  n= 26782, number of events= 3386

                                   coef  exp(coef)   se(coef)      z Pr(>|z|)
HRV_MeanNN                    3.147e-01  1.370e+00  5.602e-01  0.562 0.574235
HRV_SDNN                      3.476e-01  1.416e+00  1.284e+00  0.271 0.786618
HRV_RMSSD                     2.283e+01  8.208e+09  1.222e+01  1.868 0.061703
HRV_SDSD                     -2.192e+01  3.029e-10  1.191e+01 -1.840 0.065817
```

HRV_CVNN	-1.601e-01	8.521e-01	3.740e-01	-0.428	0.668581
HRV_CVSD	2.127e-01	1.237e+00	2.921e-01	0.728	0.466575
HRV_MedianNN	-1.061e-01	8.993e-01	1.765e-01	-0.601	0.547740
HRV_MadNN	4.062e-01	1.501e+00	2.034e-01	1.997	0.045861
HRV_MCVNN	-2.747e-01	7.598e-01	9.696e-02	-2.833	0.004606
HRV_IQRNN	1.032e-01	1.109e+00	1.066e-01	0.969	0.332552
HRV_SDRMSSD	1.127e-01	1.119e+00	3.386e-01	0.333	0.739232
HRV_Prc20NN	-1.788e-01	8.363e-01	9.391e-02	-1.904	0.056963
HRV_Prc80NN	-9.794e-02	9.067e-01	1.651e-01	-0.593	0.553129
HRV_pNN50	5.323e-02	1.055e+00	3.386e-02	1.572	0.116010
HRV_pNN20	-2.237e-02	9.779e-01	4.396e-02	-0.509	0.610803
HRV_MinNN	-2.624e-02	9.741e-01	3.499e-02	-0.750	0.453360
HRV_MaxNN	-3.356e-01	7.149e-01	1.582e-01	-2.122	0.033836
HRV_HTI	1.382e-01	1.148e+00	3.375e-02	4.096	4.21e-05
HRV_TINN	5.296e-02	1.054e+00	3.659e-02	1.447	0.147826
HRV_LF	-6.691e-02	9.353e-01	4.589e-02	-1.458	0.144885
HRV_HF	4.940e-03	1.005e+00	4.956e-02	0.100	0.920609
HRV_VHF	1.036e-02	1.010e+00	3.911e-02	0.265	0.791129
HRV_TP	NA	NA	0.000e+00	NA	NA
HRV_LFHF	-1.399e-01	8.694e-01	1.668e-01	-0.839	0.401612
HRV_LFn	1.409e-01	1.151e+00	7.710e-02	1.828	0.067528
HRV_HFn	1.372e-02	1.014e+00	5.882e-02	0.233	0.815594
HRV_LnHF	2.567e-02	1.026e+00	8.534e-02	0.301	0.763546
HRV_SD1	NA	NA	0.000e+00	NA	NA
HRV_SD2	9.793e-01	2.662e+00	1.434e+00	0.683	0.494791
HRV_SD1SD2	-1.273e-03	9.987e-01	1.039e-01	-0.012	0.990229
HRV_S	-1.826e-01	8.331e-01	3.846e-01	-0.475	0.634995
HRV_CSI	-3.395e-02	9.666e-01	3.624e-01	-0.094	0.925366
HRV_CVI	-3.893e-01	6.776e-01	2.913e-01	-1.336	0.181442
HRV_CSI_Modified	-2.784e-01	7.570e-01	4.832e-01	-0.576	0.564450
HRV_PIP	6.460e-01	1.908e+00	3.166e-01	2.040	0.041302
HRV_IALS	-5.386e-01	5.836e-01	2.972e-01	-1.812	0.070005
HRV_PSS	4.236e-03	1.004e+00	3.692e-02	0.115	0.908671
HRV_PAS	5.749e-03	1.006e+00	2.968e-02	0.194	0.846402
HRV_GI	2.453e-01	1.278e+00	1.897e-01	1.293	0.195844
HRV_SI	-4.342e-02	9.575e-01	7.746e-02	-0.561	0.575095
HRV_AI	-1.028e-01	9.023e-01	2.053e-01	-0.501	0.616413
HRV_PI	-7.616e-02	9.267e-01	3.205e-02	-2.377	0.017473
HRV_C1d	-7.610e-02	9.267e-01	8.358e-02	-0.910	0.362577
HRV_C1a	NA	NA	0.000e+00	NA	NA
HRV_SD1d	2.019e-02	1.020e+00	1.078e+00	0.019	0.985052
HRV_SD1a	-1.164e+00	3.123e-01	1.511e+00	-0.770	0.441346
HRV_C2d	3.550e-02	1.036e+00	7.980e-02	0.445	0.656403

HRV_C2a	NA	NA	0.000e+00	NA	NA
HRV_SD2d	2.966e-01	1.345e+00	1.341e+00	0.221	0.824942
HRV_SD2a	-5.340e-01	5.863e-01	1.584e+00	-0.337	0.735967
HRV_Cd	-4.800e-02	9.531e-01	1.021e-01	-0.470	0.638369
HRV_Ca	NA	NA	0.000e+00	NA	NA
HRV_SDNNd	-6.519e-01	5.211e-01	2.085e+00	-0.313	0.754567
HRV_SDNNa	5.203e-01	1.683e+00	2.689e+00	0.193	0.846575
HRV_ApEn	1.165e-01	1.124e+00	3.524e-02	3.305	0.000949
HRV_ShanEn	-3.011e-03	9.970e-01	4.120e-02	-0.073	0.941729
HRV_FuzzyEn	-5.086e-02	9.504e-01	4.969e-02	-1.024	0.306065
HRV_MSEn	-1.069e-02	9.894e-01	3.015e-02	-0.354	0.722996
HRV_CMSEn	-5.603e-02	9.455e-01	7.241e-02	-0.774	0.439012
HRV_RCMSEn	1.508e-01	1.163e+00	6.759e-02	2.232	0.025638
HRV_CD	-2.574e-01	7.730e-01	3.831e-02	-6.719	1.83e-11
HRV_HFD	2.730e-02	1.028e+00	4.532e-02	0.602	0.546971
HRV_KFD	7.953e-03	1.008e+00	1.061e-02	0.750	0.453513
HRV_LZC	-4.114e-02	9.597e-01	3.008e-02	-1.367	0.171483
HRV_DFA_alpha1	-2.706e-02	9.733e-01	7.796e-02	-0.347	0.728526
HRV_MFDFA_alpha1_Width	-1.548e-01	8.566e-01	1.680e-01	-0.921	0.357000
HRV_MFDFA_alpha1_Peak	-4.803e-02	9.531e-01	4.875e-02	-0.985	0.324504
HRV_MFDFA_alpha1_Mean	1.247e-01	1.133e+00	1.699e-01	0.734	0.462980
HRV_MFDFA_alpha1_Max	-1.133e-01	8.929e-01	1.031e-01	-1.099	0.271850
HRV_MFDFA_alpha1_Delta	6.368e-02	1.066e+00	1.068e-01	0.596	0.551053
HRV_MFDFA_alpha1_Asymmetry	-2.946e-02	9.710e-01	3.235e-02	-0.911	0.362437
HRV_MFDFA_alpha1_Fluctuation	3.577e-02	1.036e+00	1.652e-01	0.216	0.828613
HRV_MFDFA_alpha1_Increment	9.848e-03	1.010e+00	2.126e-01	0.046	0.963050

HRV_MeanNN	
HRV_SDNN	
HRV_RMSSD	.
HRV_SDSD	.
HRV_CVNN	
HRV_CVSD	
HRV_MedianNN	
HRV_MadNN	*
HRV_MCVNN	**
HRV_IQRNN	
HRV_SDRMSSD	
HRV_Prc20NN	.
HRV_Prc80NN	
HRV_pNN50	
HRV_pNN20	
HRV_MinNN	

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HRV_MaxNN                   *
HRV_HTI                     ***
HRV_TINN
HRV_LF
HRV_HF
HRV_VHF
HRV_TP
HRV_LFHF
HRV_LFn                     .
HRV_HFn
HRV_LnHF
HRV_SD1
HRV_SD2
HRV_SD1SD2
HRV_S
HRV_CSI
HRV_CVI
HRV_CSI_Modified
HRV_PIP                     *
HRV_IALS                    .
HRV_PSS
HRV_PAS
HRV_GI
HRV_SI
HRV_AI
HRV_PI                      *
HRV_C1d
HRV_C1a
HRV_SD1d
HRV_SD1a
HRV_C2d
HRV_C2a
HRV_SD2d
HRV_SD2a
HRV_Cd
HRV_Ca
HRV_SDNNd
HRV_SDNNa
HRV_ApEn                    ***
HRV_ShanEn
HRV_FuzzyEn
HRV_MSEn
HRV_CMSEn
```

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HRV_RCMSEn                    *
HRV_CD                        ***
HRV_HFD
HRV_KFD
HRV_LZC
HRV_DFA_alpha1
HRV_MFDFA_alpha1_Width
HRV_MFDFA_alpha1_Peak
HRV_MFDFA_alpha1_Mean
HRV_MFDFA_alpha1_Max
HRV_MFDFA_alpha1_Delta
HRV_MFDFA_alpha1_Asymmetry
HRV_MFDFA_alpha1_Fluctuation
HRV_MFDFA_alpha1_Increment
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

	exp(coef)	exp(-coef)	lower .95	upper .95
HRV_MeanNN	1.370e+00	7.300e-01	4.569e-01	4.107e+00
HRV_SDNN	1.416e+00	7.064e-01	1.143e-01	1.754e+01
HRV_RMSSD	8.208e+09	1.218e-10	3.268e-01	2.062e+20
HRV_SDSD	3.029e-10	3.302e+09	2.188e-20	4.192e+00
HRV_CVNN	8.521e-01	1.174e+00	4.094e-01	1.773e+00
HRV_CVSD	1.237e+00	8.084e-01	6.978e-01	2.193e+00
HRV_MedianNN	8.993e-01	1.112e+00	6.364e-01	1.271e+00
HRV_MadNN	1.501e+00	6.662e-01	1.007e+00	2.236e+00
HRV_MCVNN	7.598e-01	1.316e+00	6.283e-01	9.188e-01
HRV_IQRNN	1.109e+00	9.019e-01	8.998e-01	1.366e+00
HRV_SDRMSSD	1.119e+00	8.934e-01	5.764e-01	2.174e+00
HRV_Prc20NN	8.363e-01	1.196e+00	6.957e-01	1.005e+00
HRV_Prc80NN	9.067e-01	1.103e+00	6.560e-01	1.253e+00
HRV_pNN50	1.055e+00	9.482e-01	9.869e-01	1.127e+00
HRV_pNN20	9.779e-01	1.023e+00	8.972e-01	1.066e+00
HRV_MinNN	9.741e-01	1.027e+00	9.095e-01	1.043e+00
HRV_MaxNN	7.149e-01	1.399e+00	5.243e-01	9.747e-01
HRV_HTI	1.148e+00	8.709e-01	1.075e+00	1.227e+00
HRV_TINN	1.054e+00	9.484e-01	9.814e-01	1.133e+00
HRV_LF	9.353e-01	1.069e+00	8.548e-01	1.023e+00
HRV_HF	1.005e+00	9.951e-01	9.119e-01	1.107e+00
HRV_VHF	1.010e+00	9.897e-01	9.359e-01	1.091e+00
HRV_TP	NA	NA	NA	NA
HRV_LFHF	8.694e-01	1.150e+00	6.270e-01	1.206e+00
HRV_LFn	1.151e+00	8.685e-01	9.899e-01	1.339e+00

HRV_HFn	1.014e+00	9.864e-01	9.034e-01	1.138e+00
HRV_LnHF	1.026e+00	9.747e-01	8.680e-01	1.213e+00
HRV_SD1	NA	NA	NA	NA
HRV_SD2	2.662e+00	3.756e-01	1.601e-01	4.428e+01
HRV_SD1SD2	9.987e-01	1.001e+00	8.147e-01	1.224e+00
HRV_S	8.331e-01	1.200e+00	3.920e-01	1.771e+00
HRV_CSI	9.666e-01	1.035e+00	4.751e-01	1.967e+00
HRV_CVI	6.776e-01	1.476e+00	3.828e-01	1.199e+00
HRV_CSI_Modified	7.570e-01	1.321e+00	2.936e-01	1.951e+00
HRV_PIP	1.908e+00	5.241e-01	1.026e+00	3.549e+00
HRV_IALS	5.836e-01	1.714e+00	3.259e-01	1.045e+00
HRV_PSS	1.004e+00	9.958e-01	9.341e-01	1.080e+00
HRV_PAS	1.006e+00	9.943e-01	9.489e-01	1.066e+00
HRV_GI	1.278e+00	7.825e-01	8.813e-01	1.853e+00
HRV_SI	9.575e-01	1.044e+00	8.226e-01	1.114e+00
HRV_AI	9.023e-01	1.108e+00	6.034e-01	1.349e+00
HRV_PI	9.267e-01	1.079e+00	8.703e-01	9.867e-01
HRV_C1d	9.267e-01	1.079e+00	7.867e-01	1.092e+00
HRV_C1a	NA	NA	NA	NA
HRV_SD1d	1.020e+00	9.800e-01	1.235e-01	8.432e+00
HRV_SD1a	3.123e-01	3.202e+00	1.615e-02	6.042e+00
HRV_C2d	1.036e+00	9.651e-01	8.861e-01	1.212e+00
HRV_C2a	NA	NA	NA	NA
HRV_SD2d	1.345e+00	7.433e-01	9.713e-02	1.863e+01
HRV_SD2a	5.863e-01	1.706e+00	2.631e-02	1.306e+01
HRV_Cd	9.531e-01	1.049e+00	7.802e-01	1.164e+00
HRV_Ca	NA	NA	NA	NA
HRV_SDNNd	5.211e-01	1.919e+00	8.750e-03	3.103e+01
HRV_SDNNa	1.683e+00	5.943e-01	8.650e-03	3.273e+02
HRV_ApEn	1.124e+00	8.901e-01	1.049e+00	1.204e+00
HRV_ShanEn	9.970e-01	1.003e+00	9.197e-01	1.081e+00
HRV_FuzzyEn	9.504e-01	1.052e+00	8.622e-01	1.048e+00
HRV_MSEn	9.894e-01	1.011e+00	9.326e-01	1.050e+00
HRV_CMSEn	9.455e-01	1.058e+00	8.204e-01	1.090e+00
HRV_RCMSEn	1.163e+00	8.600e-01	1.019e+00	1.327e+00
HRV_CD	7.730e-01	1.294e+00	7.171e-01	8.333e-01
HRV_HFD	1.028e+00	9.731e-01	9.403e-01	1.123e+00
HRV_KFD	1.008e+00	9.921e-01	9.872e-01	1.029e+00
HRV_LZC	9.597e-01	1.042e+00	9.047e-01	1.018e+00
HRV_DFA_alpha1	9.733e-01	1.027e+00	8.354e-01	1.134e+00
HRV_MFDFA_alpha1_Width	8.566e-01	1.167e+00	6.162e-01	1.191e+00
HRV_MFDFA_alpha1_Peak	9.531e-01	1.049e+00	8.662e-01	1.049e+00
HRV_MFDFA_alpha1_Mean	1.133e+00	8.827e-01	8.119e-01	1.581e+00

```
HRV_MFDFA_alpha1_Max         8.929e-01  1.120e+00 7.295e-01 1.093e+00
HRV_MFDFA_alpha1_Delta       1.066e+00  9.383e-01 8.644e-01 1.314e+00
HRV_MFDFA_alpha1_Asymmetry   9.710e-01  1.030e+00 9.113e-01 1.035e+00
HRV_MFDFA_alpha1_Fluctuation 1.036e+00  9.649e-01 7.497e-01 1.433e+00
HRV_MFDFA_alpha1_Increment   1.010e+00  9.902e-01 6.658e-01 1.532e+00

Concordance= 0.59  (se = 0.005 )
Likelihood ratio test= 338.6  on 68 df,   p=<2e-16
Wald test            = 323.5  on 68 df,   p=<2e-16
Score (logrank) test = 327.3  on 68 df,   p=<2e-16
```

PH Assumption Assessment

```
cox.zph(cox_model_full)
```

```
                              chisq df    p
HRV_MeanNN                 1.10e+00  1 0.29
HRV_SDNN                   7.94e-01  1 0.37
HRV_RMSSD                  8.20e-01  1 0.37
HRV_SDSD                   8.32e-01  1 0.36
HRV_CVNN                   3.02e-02  1 0.86
HRV_CVSD                   1.03e-01  1 0.75
HRV_MedianNN               1.79e+00  1 0.18
HRV_MadNN                  3.93e-01  1 0.53
HRV_MCVNN                  6.12e-01  1 0.43
HRV_IQRNN                  7.95e-01  1 0.37
HRV_SDRMSSD                2.28e-01  1 0.63
HRV_Prc20NN                2.64e-01  1 0.61
HRV_Prc80NN                1.55e+00  1 0.21
HRV_pNN50                  8.50e-01  1 0.36
HRV_pNN20                  1.17e+00  1 0.28
HRV_MinNN                  1.49e-02  1 0.90
HRV_MaxNN                  4.55e-01  1 0.50
HRV_HTI                    9.39e-02  1 0.76
HRV_TINN                   5.92e-01  1 0.44
HRV_LF                     5.05e-01  1 0.48
HRV_HF                     2.94e-01  1 0.59
HRV_VHF                    1.67e+00  1 0.20
HRV_LFHF                   6.86e-01  1 0.41
```

HRV_LFn	2.09e-02	1	0.88
HRV_HFn	1.73e-01	1	0.68
HRV_LnHF	9.73e-02	1	0.76
HRV_SD2	6.66e-01	1	0.41
HRV_SD1SD2	7.02e-01	1	0.40
HRV_S	1.50e+00	1	0.22
HRV_CSI	5.09e-01	1	0.48
HRV_CVI	3.17e-02	1	0.86
HRV_CSI_Modified	5.10e-01	1	0.48
HRV_PIP	5.48e-02	1	0.81
HRV_IALS	1.16e-01	1	0.73
HRV_PSS	8.10e-02	1	0.78
HRV_PAS	2.00e+00	1	0.16
HRV_GI	5.72e-01	1	0.45
HRV_SI	7.15e-02	1	0.79
HRV_AI	6.37e-01	1	0.42
HRV_PI	7.35e-01	1	0.39
HRV_C1d	3.06e-01	1	0.58
HRV_SD1d	7.57e-01	1	0.38
HRV_SD1a	8.99e-01	1	0.34
HRV_C2d	2.00e-01	1	0.65
HRV_SD2d	4.67e-01	1	0.49
HRV_SD2a	7.42e-01	1	0.39
HRV_Cd	6.00e-01	1	0.44
HRV_SDNNd	6.66e-01	1	0.41
HRV_SDNNa	8.69e-01	1	0.35
HRV_ApEn	9.19e-01	1	0.34
HRV_ShanEn	3.02e-01	1	0.58
HRV_FuzzyEn	2.47e-01	1	0.62
HRV_MSEn	7.32e-02	1	0.79
HRV_CMSEn	9.87e-01	1	0.32
HRV_RCMSEn	3.56e-01	1	0.55
HRV_CD	3.82e-02	1	0.85
HRV_HFD	1.19e-01	1	0.73
HRV_KFD	9.54e-01	1	0.33
HRV_LZC	3.03e-02	1	0.86
HRV_DFA_alpha1	5.27e-01	1	0.47
HRV_MFDFA_alpha1_Width	3.60e-02	1	0.85
HRV_MFDFA_alpha1_Peak	8.66e-02	1	0.77
HRV_MFDFA_alpha1_Mean	4.83e-02	1	0.83
HRV_MFDFA_alpha1_Max	4.88e-01	1	0.48
HRV_MFDFA_alpha1_Delta	1.16e-01	1	0.73
HRV_MFDFA_alpha1_Asymmetry	1.03e-05	1	1.00

```
HRV_MFDFA_alpha1_Fluctuation 4.80e-01  1 0.49
HRV_MFDFA_alpha1_Increment   2.00e-01  1 0.66
GLOBAL                       5.46e+01 68 0.88
```

```
cox.zph(cox_model_full_complete)
```

```
                               chisq df    p
HRV_MeanNN                  1.10e+00  1 0.29
HRV_SDNN                    7.94e-01  1 0.37
HRV_RMSSD                   8.20e-01  1 0.37
HRV_SDSD                    8.32e-01  1 0.36
HRV_CVNN                    3.02e-02  1 0.86
HRV_CVSD                    1.03e-01  1 0.75
HRV_MedianNN                1.79e+00  1 0.18
HRV_MadNN                   3.93e-01  1 0.53
HRV_MCVNN                   6.12e-01  1 0.43
HRV_IQRNN                   7.95e-01  1 0.37
HRV_SDRMSSD                 2.28e-01  1 0.63
HRV_Prc20NN                 2.64e-01  1 0.61
HRV_Prc80NN                 1.55e+00  1 0.21
HRV_pNN50                   8.50e-01  1 0.36
HRV_pNN20                   1.17e+00  1 0.28
HRV_MinNN                   1.49e-02  1 0.90
HRV_MaxNN                   4.55e-01  1 0.50
HRV_HTI                     9.39e-02  1 0.76
HRV_TINN                    5.92e-01  1 0.44
HRV_LF                      5.05e-01  1 0.48
HRV_HF                      2.94e-01  1 0.59
HRV_VHF                     1.67e+00  1 0.20
HRV_LFHF                    6.86e-01  1 0.41
HRV_LFn                     2.09e-02  1 0.88
HRV_HFn                     1.73e-01  1 0.68
HRV_LnHF                    9.73e-02  1 0.76
HRV_SD2                     6.66e-01  1 0.41
HRV_SD1SD2                  7.02e-01  1 0.40
HRV_S                       1.50e+00  1 0.22
HRV_CSI                     5.09e-01  1 0.48
HRV_CVI                     3.17e-02  1 0.86
HRV_CSI_Modified            5.10e-01  1 0.48
HRV_PIP                     5.48e-02  1 0.81
HRV_IALS                    1.16e-01  1 0.73
HRV_PSS                     8.10e-02  1 0.78
```

HRV_PAS	2.00e+00	1	0.16
HRV_GI	5.72e-01	1	0.45
HRV_SI	7.15e-02	1	0.79
HRV_AI	6.37e-01	1	0.42
HRV_PI	7.35e-01	1	0.39
HRV_C1d	3.06e-01	1	0.58
HRV_SD1d	7.57e-01	1	0.38
HRV_SD1a	8.99e-01	1	0.34
HRV_C2d	2.00e-01	1	0.65
HRV_SD2d	4.67e-01	1	0.49
HRV_SD2a	7.42e-01	1	0.39
HRV_Cd	6.00e-01	1	0.44
HRV_SDNNd	6.66e-01	1	0.41
HRV_SDNNa	8.69e-01	1	0.35
HRV_ApEn	9.19e-01	1	0.34
HRV_ShanEn	3.02e-01	1	0.58
HRV_FuzzyEn	2.47e-01	1	0.62
HRV_MSEn	7.32e-02	1	0.79
HRV_CMSEn	9.87e-01	1	0.32
HRV_RCMSEn	3.56e-01	1	0.55
HRV_CD	3.82e-02	1	0.85
HRV_HFD	1.19e-01	1	0.73
HRV_KFD	9.54e-01	1	0.33
HRV_LZC	3.03e-02	1	0.86
HRV_DFA_alpha1	5.27e-01	1	0.47
HRV_MFDFA_alpha1_Width	3.60e-02	1	0.85
HRV_MFDFA_alpha1_Peak	8.66e-02	1	0.77
HRV_MFDFA_alpha1_Mean	4.83e-02	1	0.83
HRV_MFDFA_alpha1_Max	4.88e-01	1	0.48
HRV_MFDFA_alpha1_Delta	1.16e-01	1	0.73
HRV_MFDFA_alpha1_Asymmetry	1.03e-05	1	1.00
HRV_MFDFA_alpha1_Fluctuation	4.80e-01	1	0.49
HRV_MFDFA_alpha1_Increment	2.00e-01	1	0.66
GLOBAL	5.46e+01	68	0.88

The proportional hazards assumption was tested using Schoenfeld residuals. None of the variables violated the PH assumption (all $p > 0.05$), indicating that the Cox proportional hazards model was appropriate for our analysis.

Variable Selection

LASSO

```
# * LASSO doesn't allow missing values
set.seed(1234)
x <- as.matrix(data_complete %>% select(-c(time, event)))
y <- Surv(data_complete$time, data_complete$event)

# cox_model_lasso.cv <- cv.glmnet(
#     x,
#     y,
#     family = "cox",
#     alpha = 1, # 1 for LASSO, 0 for Ridge
#     nfolds = 10
# )
# plot(cox_model_lasso.cv)  # Plot partial likelihood deviance vs log(lambda)

# * We choose the range based on plot(cox_model_lasso.cv) for previous run
 ↪  when not providing lambda_seq
lambda_seq <- exp(seq(-8, -6, length.out = 100))
cox_model_lasso.cv <- cv.glmnet(
    x,
    y,
    family = "cox",
    alpha = 1, # 1 for LASSO, 0 for Ridge
    nfolds = 10,
    lambda = lambda_seq
)
print(cox_model_lasso.cv$lambda.min)
```

```
[1] 0.0007083833
```

```
print(cox_model_lasso.cv$lambda.1se)
```

```
[1] 0.002478752
```

As mentioned in the paper, we will use the value of hyperparameter `lambda.1se` that gave the most shrunk model but still was within one standard error from the value that gave the lowest error. This is shown to produce consistently better performance than `lambda.min`.

```r
cox_model_lasso <- glmnet(
    x,
    y,
    family = "cox",
    alpha = 1,
    lambda = cox_model_lasso.cv$lambda.1se
)
cox_model_lasso.coef <- coef(cox_model_lasso)
print(cox_model_lasso.coef)
```

```
73 x 1 sparse Matrix of class "dgCMatrix"
                                       s0
HRV_MeanNN                          .
HRV_SDNN                            .
HRV_RMSSD                           .
HRV_SDSD                            .
HRV_CVNN                            .
HRV_CVSD                            .
HRV_MedianNN                        .
HRV_MadNN                           .
HRV_MCVNN                           .
HRV_IQRNN                           0.0095959298
HRV_SDRMSSD                        -0.0239984153
HRV_Prc20NN                        -0.0425670353
HRV_Prc80NN                         .
HRV_pNN50                           .
HRV_pNN20                           .
HRV_MinNN                          -0.0631234047
HRV_MaxNN                           .
HRV_HTI                             0.0343782769
HRV_TINN                            .
HRV_LF                              .
HRV_HF                              .
HRV_VHF                             .
HRV_TP                              .
HRV_LFHF                            .
HRV_LFn                             .
HRV_HFn                             .
HRV_LnHF                            .
HRV_SD1                             .
HRV_SD2                             .
```

```
HRV_SD1SD2                    0.0413992298
HRV_S                         .
HRV_CSI                      -0.0005100190
HRV_CVI                       .
HRV_CSI_Modified              .
HRV_PIP                       0.0229910474
HRV_IALS                      .
HRV_PSS                       .
HRV_PAS                       0.0169771089
HRV_GI                        0.0123172955
HRV_SI                        0.0341293966
HRV_AI                        .
HRV_PI                       -0.0547899196
HRV_C1d                       .
HRV_C1a                       .
HRV_SD1d                      .
HRV_SD1a                      .
HRV_C2d                       0.0205952215
HRV_C2a                      -0.0019200457
HRV_SD2d                      .
HRV_SD2a                      .
HRV_Cd                        .
HRV_Ca                        .
HRV_SDNNd                     .
HRV_SDNNa                     .
HRV_ApEn                      0.0513880197
HRV_ShanEn                    .
HRV_FuzzyEn                   .
HRV_MSEn                      .
HRV_CMSEn                     .
HRV_RCMSEn                    0.0214151199
HRV_CD                       -0.1150440780
HRV_HFD                       .
HRV_KFD                       0.0003577586
HRV_LZC                      -0.0241285491
HRV_DFA_alpha1                .
HRV_MFDFA_alpha1_Width        .
HRV_MFDFA_alpha1_Peak         .
HRV_MFDFA_alpha1_Mean         .
HRV_MFDFA_alpha1_Max         -0.0102270849
HRV_MFDFA_alpha1_Delta        .
HRV_MFDFA_alpha1_Asymmetry    .
HRV_MFDFA_alpha1_Fluctuation  .
```

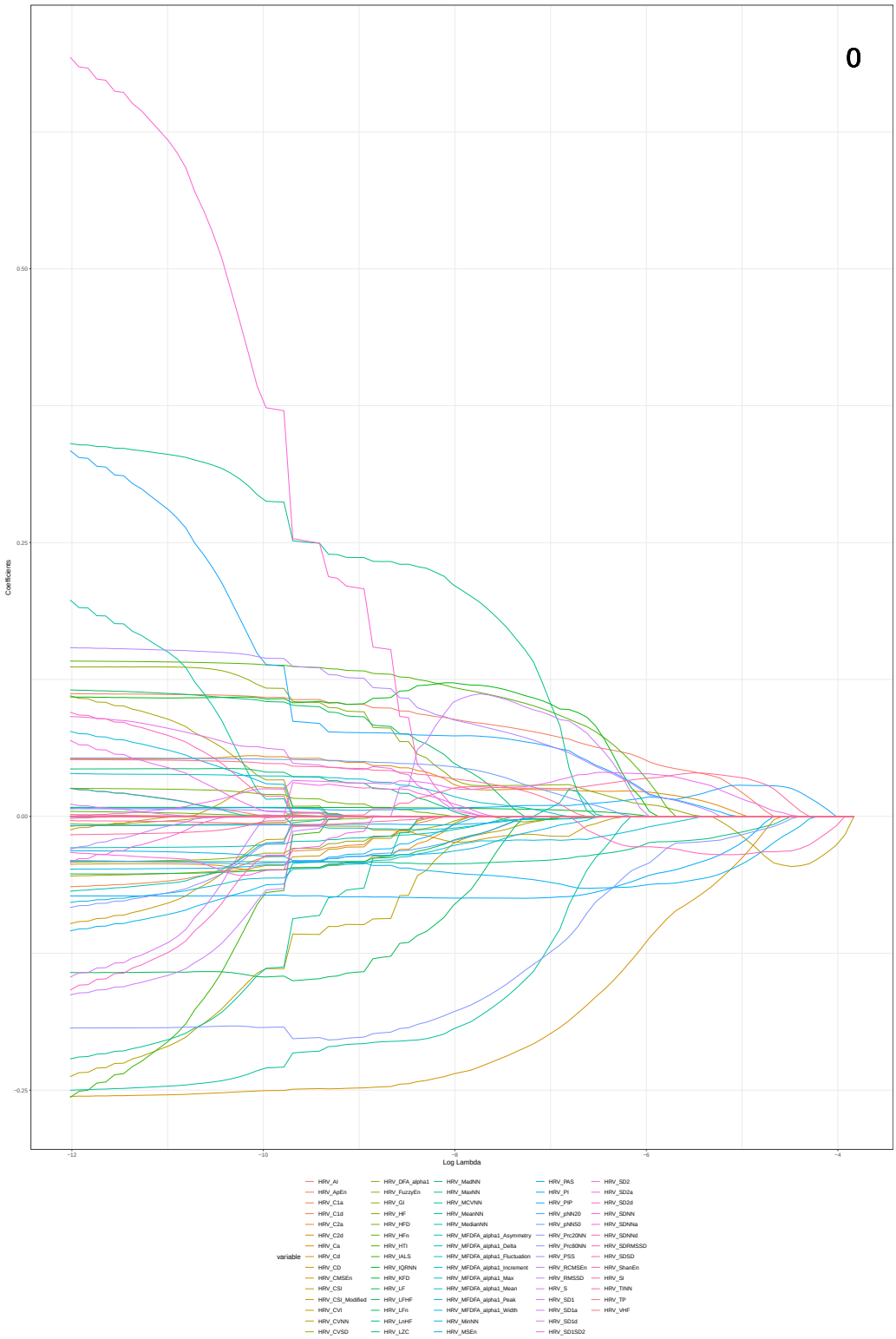
HRV_MFDFA_alpha1_Increment .

```
selected_vars <- rownames(cox_model_lasso.coef)[which(cox_model_lasso.coef !=
 ↪  0)]
print(selected_vars)
```

```
 [1] "HRV_IQRNN"            "HRV_SDRMSSD"          "HRV_Prc20NN"
 [4] "HRV_MinNN"            "HRV_HTI"              "HRV_SD1SD2"
 [7] "HRV_CSI"              "HRV_PIP"              "HRV_PAS"
[10] "HRV_GI"               "HRV_SI"               "HRV_PI"
[13] "HRV_C2d"              "HRV_C2a"              "HRV_ApEn"
[16] "HRV_RCMSEn"           "HRV_CD"               "HRV_KFD"
[19] "HRV_LZC"              "HRV_MFDFA_alpha1_Max"
```

```
# * To visualize the LASSO path, we should not supply lambda
cox_model_lasso_fullpath <- glmnet(
    x,
    y,
    family = "cox",
    alpha = 1
)
```

```
# plot(cox_model_lasso_fullpath, xvar = "lambda", label = TRUE)
autoplot(cox_model_lasso_fullpath, xvar = "lambda", label = TRUE, label.size
 ↪  = 15) +
    theme_bw() +
    theme(legend.position = "bottom") # better way of visualizing the LASSO
     ↪  path
```


0
Coefficients
0.50
0.25
0.00
−0.25
−12
−10
−8
−6
−4
Log Lambda
variable
HRV_AI
HRV_ApEn
HRV_C1a
HRV_C1d
HRV_C2a
HRV_C2d
HRV_Ca
HRV_Cd
HRV_CD
HRV_CMSEn
HRV_CSI
HRV_CSI_Modified
HRV_CVI
HRV_CVNN
HRV_CVSD
HRV_DFA_alpha1
HRV_FuzzyEn
HRV_GI
HRV_HF
HRV_HFD
HRV_HFn
HRV_HTI
HRV_IALS
HRV_IQRNN
HRV_KFD
HRV_LF
HRV_LFHF
HRV_LFn
HRV_LnHF
HRV_LZC
HRV_MadNN
HRV_MaxNN
HRV_MCVNN
HRV_MeanNN
HRV_MedianNN
HRV_MFDFA_alpha1_Asymmetry
HRV_MFDFA_alpha1_Delta
HRV_MFDFA_alpha1_Fluctuation
HRV_MFDFA_alpha1_Increment
HRV_MFDFA_alpha1_Max
HRV_MFDFA_alpha1_Mean
HRV_MFDFA_alpha1_Peak
HRV_MFDFA_alpha1_Width
HRV_MinNN
HRV_MSEn
HRV_PAS
HRV_PI
HRV_PIP
HRV_pNN20
HRV_pNN50
HRV_Prc20NN
HRV_Prc80NN
HRV_PSS
HRV_RCMSEn
HRV_RMSSD
HRV_S
HRV_SD1
HRV_SD1a
HRV_SD1d
HRV_SD1SD2
HRV_SD2
HRV_SD2a
HRV_SD2d
HRV_SDNN
HRV_SDNNa
HRV_SDNNd
HRV_SDRMSSD
HRV_SDSD
HRV_ShanEn
HRV_SI
HRV_TINN
HRV_TP
HRV_VHF

Stepwise Selection based on BIC

```
# * Stepwise selection doesn't allow missing values
cox_model_step <- MASS::stepAIC(cox_model_full_complete,
    direction = "both",
    k = log(nrow(data)), # Use BIC instead of AIC
    trace = FALSE
)
```

```
summary(cox_model_step)
```

```
Call:
coxph(formula = Surv(time, event) ~ HRV_MeanNN + HRV_SDNN + HRV_RMSSD +
    HRV_SDSD + HRV_CVNN + HRV_CVSD + HRV_MedianNN + HRV_MadNN +
    HRV_MCVNN + HRV_IQRNN + HRV_SDRMSSD + HRV_Prc20NN + HRV_Prc80NN +
    HRV_pNN50 + HRV_pNN20 + HRV_MinNN + HRV_MaxNN + HRV_HTI +
    HRV_TINN + HRV_LF + HRV_HF + HRV_VHF + HRV_TP + HRV_LFHF +
    HRV_LFn + HRV_HFn + HRV_LnHF + HRV_SD1 + HRV_SD2 + HRV_SD1SD2 +
    HRV_S + HRV_CSI + HRV_CVI + HRV_CSI_Modified + HRV_PIP +
    HRV_IALS + HRV_PSS + HRV_PAS + HRV_GI + HRV_SI + HRV_AI +
    HRV_PI + HRV_C1d + HRV_C1a + HRV_SD1d + HRV_SD1a + HRV_C2d +
    HRV_C2a + HRV_SD2d + HRV_SD2a + HRV_Cd + HRV_RCMSEn + HRV_CD +
    HRV_HFD, data = data_complete)

  n= 26782, number of events= 3386

                    coef  exp(coef)   se(coef)      z Pr(>|z|)
HRV_MeanNN      7.564e-02  1.079e+00  5.484e-01  0.138  0.89030
HRV_SDNN        5.576e-01  1.747e+00  1.253e+00  0.445  0.65624
HRV_RMSSD       2.189e+01  3.201e+09  1.185e+01  1.847  0.06470 .
HRV_SDSD       -2.120e+01  6.180e-10  1.148e+01 -1.847  0.06472 .
HRV_CVNN       -2.283e-01  7.959e-01  3.701e-01 -0.617  0.53740
HRV_CVSD        2.681e-01  1.308e+00  2.849e-01  0.941  0.34663
HRV_MedianNN   -1.269e-01  8.808e-01  1.753e-01 -0.724  0.46908
HRV_MadNN       4.480e-01  1.565e+00  2.019e-01  2.219  0.02650 *
HRV_MCVNN      -3.035e-01  7.382e-01  9.590e-02 -3.165  0.00155 **
HRV_IQRNN       9.520e-02  1.100e+00  1.063e-01  0.895  0.37068
HRV_SDRMSSD     1.530e-01  1.165e+00  3.365e-01  0.455  0.64930
HRV_Prc20NN    -1.625e-01  8.500e-01  9.311e-02 -1.745  0.08100 .
HRV_Prc80NN    -9.657e-02  9.079e-01  1.658e-01 -0.582  0.56032
```

```
HRV_pNN50         5.276e-02  1.054e+00  3.140e-02  1.680  0.09294 .
HRV_pNN20        -3.467e-02  9.659e-01  4.062e-02 -0.854  0.39333
HRV_MinNN        -1.644e-02  9.837e-01  3.407e-02 -0.483  0.62935
HRV_MaxNN        -3.078e-01  7.351e-01  1.544e-01 -1.994  0.04617 *
HRV_HTI           1.329e-01  1.142e+00  3.081e-02  4.313 1.61e-05 ***
HRV_TINN          5.595e-02  1.058e+00  3.656e-02  1.530  0.12593
HRV_LF           -1.127e+00  3.239e-01  5.124e+02 -0.002  0.99824
HRV_HF           -2.680e+00  6.859e-02  1.300e+03 -0.002  0.99836
HRV_VHF          -1.001e+00  3.674e-01  4.914e+02 -0.002  0.99837
HRV_TP            3.706e+00  4.067e+01  1.800e+03  0.002  0.99836
HRV_LFHF         -1.430e-01  8.667e-01  1.627e-01 -0.879  0.37943
HRV_LFn           1.495e-01  1.161e+00  7.499e-02  1.994  0.04614 *
HRV_HFn           1.191e-02  1.012e+00  5.815e-02  0.205  0.83770
HRV_LnHF          3.399e-02  1.035e+00  8.430e-02  0.403  0.68681
HRV_SD1                  NA         NA  0.000e+00     NA       NA
HRV_SD2           9.298e-01  2.534e+00  1.402e+00  0.663  0.50715
HRV_SD1SD2        3.317e-02  1.034e+00  9.595e-02  0.346  0.72953
HRV_S            -2.282e-01  7.960e-01  3.775e-01 -0.605  0.54551
HRV_CSI          -3.304e-02  9.675e-01  3.586e-01 -0.092  0.92659
HRV_CVI          -4.225e-01  6.554e-01  2.866e-01 -1.474  0.14051
HRV_CSI_Modified -2.870e-01  7.505e-01  3.126e-01 -0.918  0.35856
HRV_PIP           6.060e-01  1.833e+00  3.116e-01  1.945  0.05180 .
HRV_IALS         -4.686e-01  6.259e-01  2.917e-01 -1.607  0.10814
HRV_PSS          -7.486e-03  9.925e-01  3.631e-02 -0.206  0.83667
HRV_PAS          -6.844e-04  9.993e-01  2.947e-02 -0.023  0.98147
HRV_GI            2.707e-01  1.311e+00  1.866e-01  1.451  0.14683
HRV_SI           -5.510e-02  9.464e-01  7.586e-02 -0.726  0.46760
HRV_AI           -1.271e-01  8.807e-01  2.029e-01 -0.626  0.53110
HRV_PI           -8.850e-02  9.153e-01  3.162e-02 -2.799  0.00513 **
HRV_C1d          -5.642e-02  9.451e-01  7.689e-02 -0.734  0.46309
HRV_C1a                  NA         NA  0.000e+00     NA       NA
HRV_SD1d         -1.615e-01  8.509e-01  7.370e-01 -0.219  0.82659
HRV_SD1a         -8.564e-01  4.247e-01  1.019e+00 -0.840  0.40073
HRV_C2d           6.128e-02  1.063e+00  6.087e-02  1.007  0.31403
HRV_C2a                  NA         NA  0.000e+00     NA       NA
HRV_SD2d         -6.930e-02  9.331e-01  5.377e-01 -0.129  0.89746
HRV_SD2a         -1.531e-01  8.581e-01  5.569e-01 -0.275  0.78343
HRV_Cd           -7.895e-02  9.241e-01  8.777e-02 -0.900  0.36835
HRV_RCMSEn        1.190e-01  1.126e+00  3.009e-02  3.954 7.68e-05 ***
HRV_CD           -2.598e-01  7.712e-01  3.173e-02 -8.186 2.69e-16 ***
HRV_HFD           4.636e-02  1.047e+00  4.188e-02  1.107  0.26834
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

	exp(coef)	exp(-coef)	lower .95	upper .95
HRV_MeanNN	1.079e+00	9.271e-01	3.682e-01	3.160e+00
HRV_SDNN	1.747e+00	5.726e-01	1.499e-01	2.035e+01
HRV_RMSSD	3.201e+09	3.124e-10	2.634e-01	3.891e+19
HRV_SDSD	6.180e-10	1.618e+09	1.046e-19	3.651e+00
HRV_CVNN	7.959e-01	1.256e+00	3.853e-01	1.644e+00
HRV_CVSD	1.308e+00	7.648e-01	7.481e-01	2.285e+00
HRV_MedianNN	8.808e-01	1.135e+00	6.247e-01	1.242e+00
HRV_MadNN	1.565e+00	6.389e-01	1.054e+00	2.325e+00
HRV_MCVNN	7.382e-01	1.355e+00	6.117e-01	8.908e-01
HRV_IQRNN	1.100e+00	9.092e-01	8.929e-01	1.355e+00
HRV_SDRMSSD	1.165e+00	8.581e-01	6.026e-01	2.253e+00
HRV_Prc20NN	8.500e-01	1.176e+00	7.083e-01	1.020e+00
HRV_Prc80NN	9.079e-01	1.101e+00	6.560e-01	1.257e+00
HRV_pNN50	1.054e+00	9.486e-01	9.912e-01	1.121e+00
HRV_pNN20	9.659e-01	1.035e+00	8.920e-01	1.046e+00
HRV_MinNN	9.837e-01	1.017e+00	9.202e-01	1.052e+00
HRV_MaxNN	7.351e-01	1.360e+00	5.432e-01	9.948e-01
HRV_HTI	1.142e+00	8.756e-01	1.075e+00	1.213e+00
HRV_TINN	1.058e+00	9.456e-01	9.844e-01	1.136e+00
HRV_LF	3.239e-01	3.087e+00	0.000e+00	Inf
HRV_HF	6.859e-02	1.458e+01	0.000e+00	Inf
HRV_VHF	3.674e-01	2.722e+00	0.000e+00	Inf
HRV_TP	4.067e+01	2.459e-02	0.000e+00	Inf
HRV_LFHF	8.667e-01	1.154e+00	6.301e-01	1.192e+00
HRV_LFn	1.161e+00	8.611e-01	1.003e+00	1.345e+00
HRV_HFn	1.012e+00	9.882e-01	9.030e-01	1.134e+00
HRV_LnHF	1.035e+00	9.666e-01	8.770e-01	1.220e+00
HRV_SD1	NA	NA	NA	NA
HRV_SD2	2.534e+00	3.946e-01	1.624e-01	3.954e+01
HRV_SD1SD2	1.034e+00	9.674e-01	8.565e-01	1.248e+00
HRV_S	7.960e-01	1.256e+00	3.798e-01	1.668e+00
HRV_CSI	9.675e-01	1.034e+00	4.790e-01	1.954e+00
HRV_CVI	6.554e-01	1.526e+00	3.737e-01	1.149e+00
HRV_CSI_Modified	7.505e-01	1.332e+00	4.067e-01	1.385e+00
HRV_PIP	1.833e+00	5.455e-01	9.953e-01	3.376e+00
HRV_IALS	6.259e-01	1.598e+00	3.534e-01	1.109e+00
HRV_PSS	9.925e-01	1.008e+00	9.244e-01	1.066e+00
HRV_PAS	9.993e-01	1.001e+00	9.432e-01	1.059e+00
HRV_GI	1.311e+00	7.628e-01	9.094e-01	1.890e+00
HRV_SI	9.464e-01	1.057e+00	8.156e-01	1.098e+00
HRV_AI	8.807e-01	1.135e+00	5.918e-01	1.311e+00

```
HRV_PI           9.153e-01  1.093e+00 8.603e-01 9.738e-01
HRV_C1d          9.451e-01  1.058e+00 8.129e-01 1.099e+00
HRV_C1a                 NA         NA        NA        NA
HRV_SD1d         8.509e-01  1.175e+00 2.007e-01 3.608e+00
HRV_SD1a         4.247e-01  2.355e+00 5.762e-02 3.130e+00
HRV_C2d          1.063e+00  9.406e-01 9.436e-01 1.198e+00
HRV_C2a                 NA         NA        NA        NA
HRV_SD2d         9.331e-01  1.072e+00 3.252e-01 2.677e+00
HRV_SD2a         8.581e-01  1.165e+00 2.880e-01 2.556e+00
HRV_Cd           9.241e-01  1.082e+00 7.780e-01 1.098e+00
HRV_RCMSEn       1.126e+00  8.878e-01 1.062e+00 1.195e+00
HRV_CD           7.712e-01  1.297e+00 7.247e-01 8.207e-01
HRV_HFD          1.047e+00  9.547e-01 9.649e-01 1.137e+00

Concordance= 0.587  (se = 0.005 )
Likelihood ratio test= 320.9  on 51 df,   p=<2e-16
Wald test            = 306.5  on 51 df,   p=<2e-16
Score (logrank) test = 309.9  on 51 df,   p=<2e-16
```

Summary of Variable Selection

We will compare the selection of variables from all models we have built.

```
# Obtain the selected variables from all models
variable_names_all <- colnames(data) %>%
    setdiff(c("time", "event"))

variable_names_univariate <- results_univariate %>%
    filter(p_value < 0.05) %>%
    pull(predictor)

variable_names_multivariate <- summary(cox_model_full_complete)$coefficients
 ↪  %>%
    as.data.frame() %>%
    rownames_to_column(var = "predictor") %>% # transpose, "predictor" will
     ↪  now be the column name
    filter(`Pr(>|z|)` < 0.05) %>%
    pull(predictor)

variable_names_lasso <-
 ↪  rownames(cox_model_lasso.coef)[which(cox_model_lasso.coef != 0)]
```

```r
variable_names_step <- cox_model_step$coefficients %>%
    names()
```

```r
variable_selection_matrix <- matrix(
    0,
    nrow = length(variable_names_all),
    ncol = 4 # univariate, multivariate, lasso, stepwise
)
colnames(variable_selection_matrix) <- c("univariate", "multivariate",
 ↪  "lasso", "stepwise")
rownames(variable_selection_matrix) <- variable_names_all

for (variable in variable_names_all) {
    if (variable %in% variable_names_univariate) {
        variable_selection_matrix[variable, "univariate"] <- 1
    }
    if (variable %in% variable_names_multivariate) {
        variable_selection_matrix[variable, "multivariate"] <- 1
    }
    if (variable %in% variable_names_lasso) {
        variable_selection_matrix[variable, "lasso"] <- 1
    }
    if (variable %in% variable_names_step) {
        variable_selection_matrix[variable, "stepwise"] <- 1
    }
}
```

```r
symbol_selected <- "*"

selection_table <- data.frame(
    Variable = variable_names_all,
    Univariate = ifelse(variable_selection_matrix[, "univariate"] == 1,
     ↪  symbol_selected, ""),
    Multivariate = ifelse(variable_selection_matrix[, "multivariate"] == 1,
     ↪  symbol_selected, ""),
    LASSO = ifelse(variable_selection_matrix[, "lasso"] == 1,
     ↪  symbol_selected, ""),
    Stepwise = ifelse(variable_selection_matrix[, "stepwise"] == 1,
     ↪  symbol_selected, "")
) %>%
```

```
    mutate(Num_Selected = rowSums(variable_selection_matrix)) %>%
    arrange(desc(Num_Selected), Variable) %>%
    as.data.frame() %>%
    remove_rownames()

variable_categories <- sapply(variable_names_all, determine_category)
category_colors <- c(
    "covariate" = "#FFB6C1", #
    "time"      = "#1E90FF", #
    "frequency" = "#32CD32", #
    "poincare"  = "#FF4500", #
    "entropy"   = "#FF8C00", #
    "fractal"   = "#FFD700", #
    "unknown"   = "#000000" #
)
category_colors_names <- c(
    "covariate"  = "pink",      #
    "time"       = "blue",      #
    "frequency"  = "green",     #
    "poincare"   = "red",       #
    "entropy"    = "orange",    #
    "fractal"    = "gold"       #
)
category_legend <- sapply(names(category_colors_names), function(cat) {
    sprintf("%s: %s",
            tools::toTitleCase(cat),
            tools::toTitleCase(category_colors_names[cat]))
}) %>%
    paste(collapse = "; ")


selection_table %>%
    kbl(
        caption = "Variable Selection by Different Models",
        align = c("|l", "c", "c", "c", "c", "c|"),
        col.names = c("Variable", "Univariate", "Multivariate", "LASSO",
         ↪  "Stepwise", "Selected Times"),
        longtable = TRUE
    ) %>%
    kable_styling(
        bootstrap_options = c("striped", "hover", "condensed", "responsive"),
        position = "center",
```

```
    font_size = 9,
    latex_options = c("repeat_header", "striped", "HOLD_position")
) %>%
# Add color for different categories of variables
column_spec(1,
    color =
     ↪  category_colors[variable_categories[selection_table$Variable]],
    bold = TRUE
) %>%
# Add a header colname for four columns: Univariate, Multivariate, LASSO,
 ↪  Stepwise
add_header_above(c(
    " " = 1,
    "Selection Methods" = 4,
    " " = 1
)) %>%
footnote(
    general = sprintf("%s", category_legend),
    general_title = "Note:"
)
```

Table 1: Variable Selection by Different Models

	Selection Methods				
Variable	Univariate	Multivariate	LASSO	Stepwise	Selected Times
HRV_CD	*	*	*	*	4
HRV_HTI	*	*	*	*	4
HRV_PI	*	*	*	*	4
HRV_PIP	*	*	*	*	4
HRV_RCMSEn	*	*	*	*	4
HRV_ApEn	*	*	*		3
HRV_C2a	*		*	*	3
HRV_C2d	*		*	*	3
HRV_CSI	*		*	*	3
HRV_GI	*		*	*	3
HRV_IQRNN	*		*	*	3
HRV_MCVNN	*	*		*	3
HRV_MadNN	*	*		*	3
HRV_MaxNN	*	*		*	3
HRV_MinNN	*		*	*	3
HRV_PAS	*		*	*	3
HRV_Prc20NN	*		*	*	3
HRV_SD1SD2	*		*	*	3
HRV_SDRMSSD	*		*	*	3
HRV_SI	*		*	*	3

Table 1: Variable Selection by Different Models *(continued)*

Variable	Univariate	Multivariate	LASSO	Stepwise	Selected Times
HRV_AI	*			*	2
HRV_C1a	*			*	2
HRV_C1d	*			*	2
HRV_CSI_Modified	*			*	2
HRV_CVI	*			*	2
HRV_CVNN	*			*	2
HRV_CVSD	*			*	2
HRV_Cd	*			*	2
HRV_HFD	*			*	2
HRV_IALS	*			*	2
HRV_LF	*			*	2
HRV_LFn	*			*	2
HRV_LZC	*		*		2
HRV_MFDFA_alpha1_Max	*		*		2
HRV_MeanNN	*			*	2
HRV_MedianNN	*			*	2
HRV_PSS	*			*	2
HRV_Prc80NN	*			*	2
HRV_RMSSD	*			*	2
HRV_SD1	*			*	2
HRV_SD1a	*			*	2
HRV_SD1d	*			*	2
HRV_SD2	*			*	2
HRV_SD2a	*			*	2
HRV_SD2d	*			*	2
HRV_SDNN	*			*	2
HRV_SDSD	*			*	2
HRV_TINN	*			*	2
HRV_VHF	*			*	2
HRV_pNN20	*			*	2
HRV_CMSEn	*				1
HRV_Ca	*				1
HRV_DFA_alpha1	*				1
HRV_FuzzyEn	*				1
HRV_HF				*	1
HRV_HFn				*	1
HRV_KFD			*		1
HRV_LFHF				*	1
HRV_LnHF				*	1
HRV_MFDFA_alpha1_Asymmetry	*				1
HRV_MFDFA_alpha1_Delta	*				1
HRV_MFDFA_alpha1_Peak	*				1
HRV_S				*	1
HRV_SDNNa	*				1
HRV_SDNNd	*				1
HRV_TP				*	1
HRV_pNN50				*	1
HRV_MFDFA_alpha1_Fluctuation					0

Table 1: Variable Selection by Different Models *(continued)*

Variable	Univariate	Multivariate	LASSO	Stepwise	Selected Times
HRV_MFDFA_alpha1_Increment					0
HRV_MFDFA_alpha1_Mean					0
HRV_MFDFA_alpha1_Width					0
HRV_MSEn					0
HRV_ShanEn					0

Note:

Covariate: Pink; Time: Blue; Frequency: Green; Poincare: Red; Entropy: Orange; Fractal: Gold