statistical method

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2023-12-06

```r
library(biostat3)
write_csv(brv,"brv.csv")
## Creating times relativ to spouse death (year=0)
brv2 <- mutate(brv,
               id=NULL,
               y_before_sp_dth =  as.numeric(doe -dosp) / 365.24,
               y_after_sp_dth = as.numeric(dox - dosp) / 365.24)

## Splitting at spouse death (year=0)
brvSplit <- survSplit(brv2, cut = 0, end="y_after_sp_dth", start="y_before_sp_dth", id="id",event="fail

## Calculating risk times
brvSplit <- mutate(brvSplit,
                   t_sp_at_risk =   y_after_sp_dth - y_before_sp_dth,
                   brv = ifelse(y_after_sp_dth > 0, 1, 0))
```

The mutate function from the dplyr package (assumed as it's not explicitly loaded but commonly used for such operations) is used to modify the brv data frame. Two new columns are created: y_before_sp_dth and y_after_sp_dth. These represent the number of years before and after the death of a spouse (dosp), calculated by subtracting the date of the event of interest (doe or dox) from the date of the spouse's death and converting the difference into years (dividing by 365.24, the average number of days in a year accounting for leap years).

The survSplit function from the survival package is used to split the data into periods before and after the spouse's death. This is done by specifying a cut point at year 0 (the year of the spouse's death). The function creates new observations in the dataset, splitting any observation that spans the time point 0 into two, one before and one after the spouse's death. Further Data Transformation:

Another mutate function is used to calculate two new variables: t_sp_at_risk (the time at risk after the spouse's death, calculated as the difference between y_after_sp_dth and y_before_sp_dth) and brv (a binary indicator set to 1 if the event occurred after the spouse's death, otherwise 0).

```r
summary(brvSplit)
```

```
##      couple           dob                   doe                   dox
##  Min.   :  1.0   Min.   :1888-02-22   Min.   :1981-01-15   Min.   :1981-03-13
##  1st Qu.: 65.5   1st Qu.:1900-11-23   1st Qu.:1981-03-10   1st Qu.:1985-02-27
##  Median :131.0   Median :1903-02-24   Median :1981-04-08   Median :1988-09-04
##  Mean   :132.0   Mean   :1902-05-28   Mean   :1981-04-10   Mean   :1987-11-08
##  3rd Qu.:196.0   3rd Qu.:1904-10-28   3rd Qu.:1981-05-11   3rd Qu.:1991-01-01
##  Max.   :266.0   Max.   :1906-03-12   Max.   :1981-10-23   Max.   :1991-01-01
##       dosp                group           disab            health
##  Min.   :1981-05-22   Min.   :1.000   Min.   :0.0000   Min.   :0.000
##  1st Qu.:1983-10-16   1st Qu.:1.000   1st Qu.:0.0000   1st Qu.:1.000
```

```
##  Median :1986-12-14   Median :1.000   Median :0.0000   Median :2.000
##  Mean   :1989-07-20   Mean   :1.544   Mean   :0.5568   Mean   :1.532
##  3rd Qu.:2000-01-01   3rd Qu.:2.000   3rd Qu.:1.0000   3rd Qu.:2.000
##  Max.   :2000-01-01   Max.   :3.000   Max.   :3.0000   Max.   :2.000
##       sex              id         y_before_sp_dth   y_after_sp_dth
##  Min.   :1.000   Min.   :  1.0   Min.   :-18.960   Min.   :-18.804
##  1st Qu.:1.000   1st Qu.:111.5   1st Qu.:-18.618   1st Qu.: -9.000
##  Median :1.000   Median :221.0   Median : -4.288   Median :  0.000
##  Mean   :1.468   Mean   :210.8   Mean   : -7.259   Mean   : -2.871
##  3rd Qu.:2.000   3rd Qu.:309.5   3rd Qu.:  0.000   3rd Qu.:  0.690
##  Max.   :2.000   Max.   :399.0   Max.   :  0.000   Max.   :  9.583
##       fail          t_sp_at_risk          brv
##  Min.   :0.0000   Min.   :0.008214   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.:1.794710   1st Qu.:0.0000
##  Median :1.0000   Median :3.926186   Median :0.0000
##  Mean   :0.5009   Mean   :4.388663   Mean   :0.2811
##  3rd Qu.:1.0000   3rd Qu.:6.654529   3rd Qu.:1.0000
##  Max.   :1.0000   Max.   :9.889388   Max.   :1.0000
```

```r
library(skimr)
skimr::skim(brvSplit)
```

Table 1: Data summary

Name	brvSplit
Number of rows	555
Number of columns	15
Column type frequency:	
Date	4
numeric	11
Group variables	None

Variable type: Date

skim_variable	n_missing	complete_rate	min	max	median	n_unique
dob	0	1	1888-02-22	1906-03-12	1903-02-24	376
doe	0	1	1981-01-15	1981-10-23	1981-04-08	93
dox	0	1	1981-03-13	1991-01-01	1988-09-04	264
dosp	0	1	1981-05-22	2000-01-01	1986-12-14	235

Variable type: numeric

skim_variable	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
couple	0	1	131.99	76.60	1.00	65.50	131.00	196.00	266.00	
group	0	1	1.54	0.72	1.00	1.00	1.00	2.00	3.00	
disab	0	1	0.56	0.97	0.00	0.00	0.00	1.00	3.00	
health	0	1	1.53	0.61	0.00	1.00	2.00	2.00	2.00	
sex	0	1	1.47	0.50	1.00	1.00	1.00	2.00	2.00	
id	0	1	210.77	115.77	1.00	111.50	221.00	309.50	399.00	

skim_variable	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
y_before_sp_dth	0	1	-7.26	7.67	-18.96	-18.62	-4.29	0.00	0.00	
y_after_sp_dth	0	1	-2.87	7.04	-18.80	-9.00	0.00	0.69	9.58	
fail	0	1	0.50	0.50	0.00	0.00	1.00	1.00	1.00	
t_sp_at_risk	0	1	4.39	2.99	0.01	1.79	3.93	6.65	9.89	
brv	0	1	0.28	0.45	0.00	0.00	0.00	1.00	1.00	

```
brvSplit2 <- mutate(brvSplit,
                    sex = as.factor(sex),
                    brv = as.factor(brv))
## Translate time scale from years from spouse death to ages
brvSplit3 <- brvSplit2 %>%
    mutate(age_sp_dth =  as.numeric(dosp - dob) / 365.24, # Age at spouse death
           age_start = age_sp_dth + y_before_sp_dth,      # Age at start of timeband
           age_end = age_sp_dth + y_after_sp_dth)         # Age at end of timeband

age_cat <- seq(70,100,5) # Split at these ages
brvSplit4 <- survSplit(brvSplit3, cut=age_cat, start="age_start", end="age_end", event="fail", zero = 0)

brvSplit4 <- mutate(brvSplit4,
                    t_at_risk = age_end- age_start, # Creating new time at risk
                    age = cut(age_end, age_cat))   # Creating age band category

## Calculate crude rates
survRate(Surv(t_at_risk, fail) ~ age, data=brvSplit4)
```

```
##                     age       tstop event       rate      lower      upper
## age=(75,80]   (75,80]  703.612419    45 0.06395566 0.04664970 0.08557771
## age=(80,85]   (80,85] 1184.684043   123 0.10382515 0.08628885 0.12387811
## age=(85,90]   (85,90]  490.021356    95 0.19386910 0.15685168 0.23699492
## age=(90,95]   (90,95]   55.090352    12 0.21782399 0.11255283 0.38049467
## age=(95,100] (95,100]    2.299858     3 1.30442857 0.26900453 3.81209383
```

```
summary(coxph(Surv(age_start, age_end, fail) ~ brv,
              data = brvSplit4))
```

```
## Call:
## coxph(formula = Surv(age_start, age_end, fail) ~ brv, data = brvSplit4)
##
##   n= 1036, number of events= 278
##
##         coef exp(coef) se(coef)      z Pr(>|z|)
## brv1 -0.2070    0.8131   0.1390 -1.488    0.137
##
##      exp(coef) exp(-coef) lower .95 upper .95
## brv1    0.8131       1.23    0.6191     1.068
##
## Concordance= 0.511  (se = 0.014 )
## Likelihood ratio test= 2.26  on 1 df,   p=0.1
## Wald test            = 2.22  on 1 df,   p=0.1
## Score (logrank) test = 2.22  on 1 df,   p=0.1
```

```r
summary(coxph(Surv(age_start, age_end, fail) ~ brv + sex,
              data = brvSplit4))
```

```
## Call:
## coxph(formula = Surv(age_start, age_end, fail) ~ brv + sex, data = brvSplit4)
##
##   n= 1036, number of events= 278
##
##           coef exp(coef) se(coef)      z Pr(>|z|)
## brv1 -0.07842   0.92458  0.14245 -0.551 0.581971
## sex2 -0.47291   0.62318  0.13075 -3.617 0.000298 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##      exp(coef) exp(-coef) lower .95 upper .95
## brv1    0.9246      1.082    0.6993    1.2224
## sex2    0.6232      1.605    0.4823    0.8052
##
## Concordance= 0.56  (se = 0.018 )
## Likelihood ratio test= 15.85  on 2 df,   p=4e-04
## Wald test            = 15.21  on 2 df,   p=5e-04
## Score (logrank) test = 15.51  on 2 df,   p=4e-04
```

```r
summary(coxph(Surv(age_start, age_end, fail) ~ brv,
              data = brvSplit4))
```

```
## Call:
## coxph(formula = Surv(age_start, age_end, fail) ~ brv, data = brvSplit4)
##
##   n= 1036, number of events= 278
##
##          coef exp(coef) se(coef)      z Pr(>|z|)
## brv1 -0.2070    0.8131   0.1390 -1.488    0.137
##
##      exp(coef) exp(-coef) lower .95 upper .95
## brv1    0.8131       1.23    0.6191     1.068
##
## Concordance= 0.511  (se = 0.014 )
## Likelihood ratio test= 2.26  on 1 df,   p=0.1
## Wald test            = 2.22  on 1 df,   p=0.1
## Score (logrank) test = 2.22  on 1 df,   p=0.1
```

```r
summary(coxph(Surv(age_start, age_end, fail) ~ brv + sex,
              data = brvSplit4))
```

```
## Call:
## coxph(formula = Surv(age_start, age_end, fail) ~ brv + sex, data = brvSplit4)
##
##   n= 1036, number of events= 278
##
##           coef exp(coef) se(coef)      z Pr(>|z|)
## brv1 -0.07842   0.92458  0.14245 -0.551 0.581971
## sex2 -0.47291   0.62318  0.13075 -3.617 0.000298 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
##      exp(coef) exp(-coef) lower .95 upper .95
## brv1    0.9246      1.082    0.6993    1.2224
## sex2    0.6232      1.605    0.4823    0.8052
##
## Concordance= 0.56  (se = 0.018 )
## Likelihood ratio test= 15.85  on 2 df,   p=4e-04
## Wald test            = 15.21  on 2 df,   p=5e-04
## Score (logrank) test = 15.51  on 2 df,   p=4e-04
```

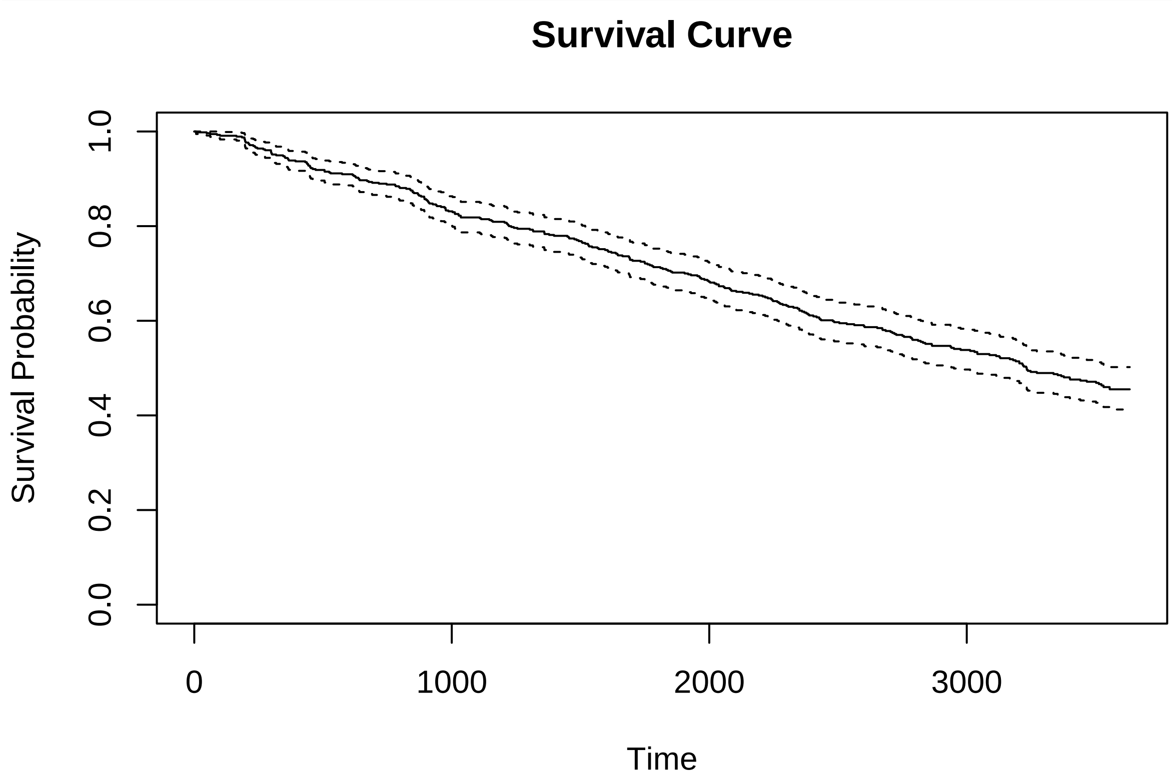
```
surv_object <- Surv(time = brvSplit$dox-brvSplit$doe, event = brvSplit$fail)

# Generate the life table using Kaplan-Meier estimate
life_table <- survfit(surv_object ~ 1)

# Print the life table
print(life_table)
```

```
## Call: survfit(formula = surv_object ~ 1)
##
##         n events median 0.95LCL 0.95UCL
## [1,] 555    278   3233    2950      NA
```

```
life_table
```

```
## Call: survfit(formula = surv_object ~ 1)
##
##         n events median 0.95LCL 0.95UCL
## [1,] 555    278   3233    2950      NA
```

```
plot(life_table, main = "Survival Curve", xlab = "Time", ylab = "Survival Probability")
```



male

```
lifetable1=lifetab2(Surv(time = brvSplit$dox-brvSplit$doe, brvSplit$fail==1) ~ 1, brvSplit[brvSplit$sex
print(lifetable1)
```

```
##           tstart tstop nsubs nlost  nrisk nevent        surv          pdf
## 0-300          0   300   295     1  294.5     25  1.00000000 0.0002829655
## 300-600      300   600   269     3  267.5     25  0.91511036 0.0002850811
## 600-900      600   900   241     4  239.0     29  0.82958602 0.0003355369
## 900-1200     900  1200   208     3  206.5     26  0.72892496 0.0003059249
## 1200-1500   1200  1500   179     7  175.5     22  0.63714748 0.0002662345
## 1500-1800   1500  1800   150     8  146.0     29  0.55727714 0.0003689735
## 1800-2100   1800  2100   113     9  108.5     26  0.44658511 0.0003567193
## 2100-2400   2100  2400    78    14   71.0     26  0.33956932 0.0004144978
## 2400-2700   2400  2700    38     1   37.5     16  0.21521999 0.0003060907
## 2700-3000   2700  3000    21    13   14.5     19  0.12339280 0.0005389570
## 3000-Inf    3000   Inf   -11   214 -118.0     35 -0.03829432           NA
##                 hazard    se.surv       se.pdf    se.hazard
## 0-300     0.0002955083 0.00000000 5.413775e-05 5.904356e-05
## 300-600   0.0003267974 0.01624132 5.452184e-05 6.528090e-05
## 600-900   0.0004305865 0.02195479 5.907645e-05 7.979095e-05
## 900-1200  0.0004478898 0.02606034 5.714913e-05 8.763995e-05
## 1200-1500 0.0004457953 0.02832075 5.438765e-05 9.483115e-05
## 1500-1800 0.0007351077 0.02944824 6.436005e-05 1.356737e-04
## 1800-2100 0.0009075044 0.02992482 6.551898e-05 1.763196e-04
## 2100-2400 0.0014942529 0.02920041 7.388269e-05 2.855912e-04
## 2400-2700 0.0018079096 0.02682268 6.937243e-05 4.350404e-04
## 2700-3000 0.0126666667 0.02320880 7.437499e-05          NaN
## 3000-Inf            NA        NaN           NA           NA
```

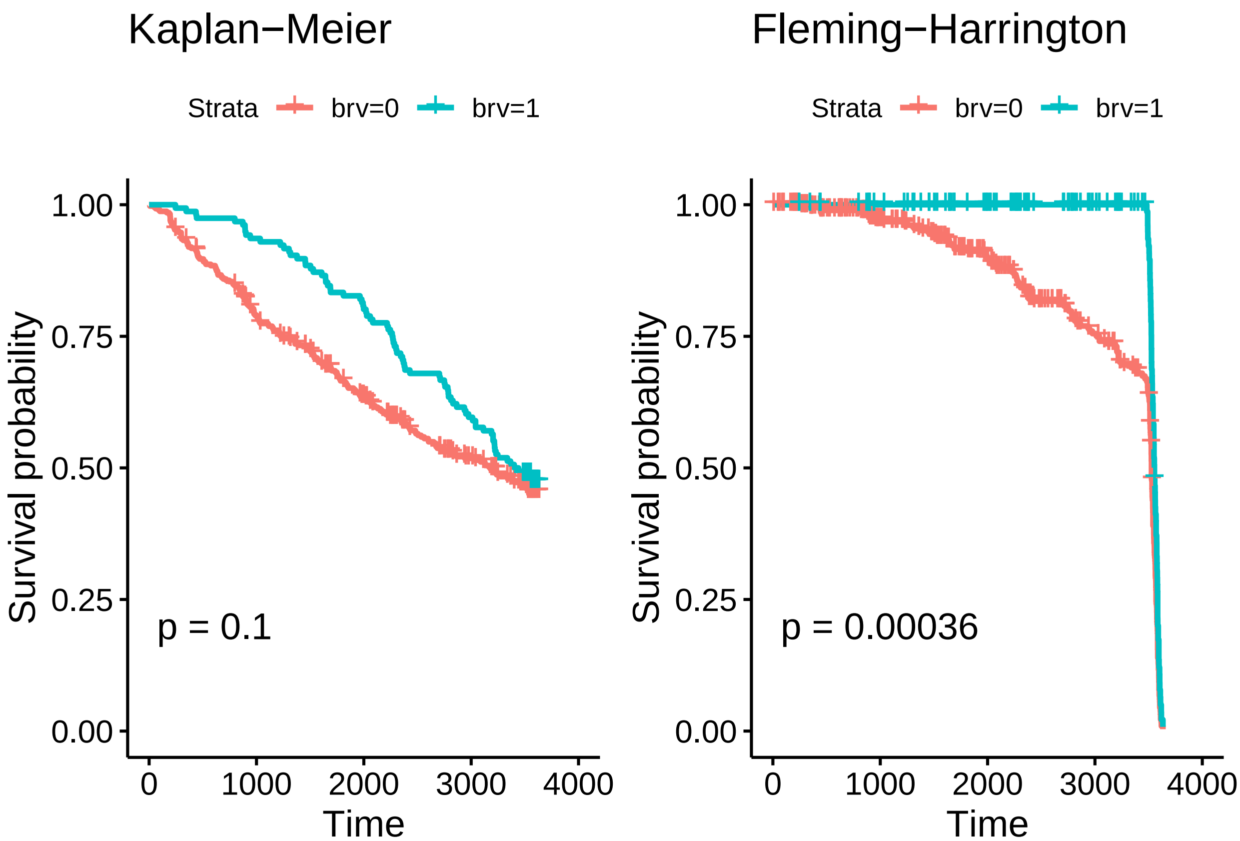
female

```
lifetable2=lifetab2(Surv(time = brvSplit$dox-brvSplit$doe, brvSplit$fail==1) ~ 1, brvSplit[brvSplit$sex
print(lifetable2)
```

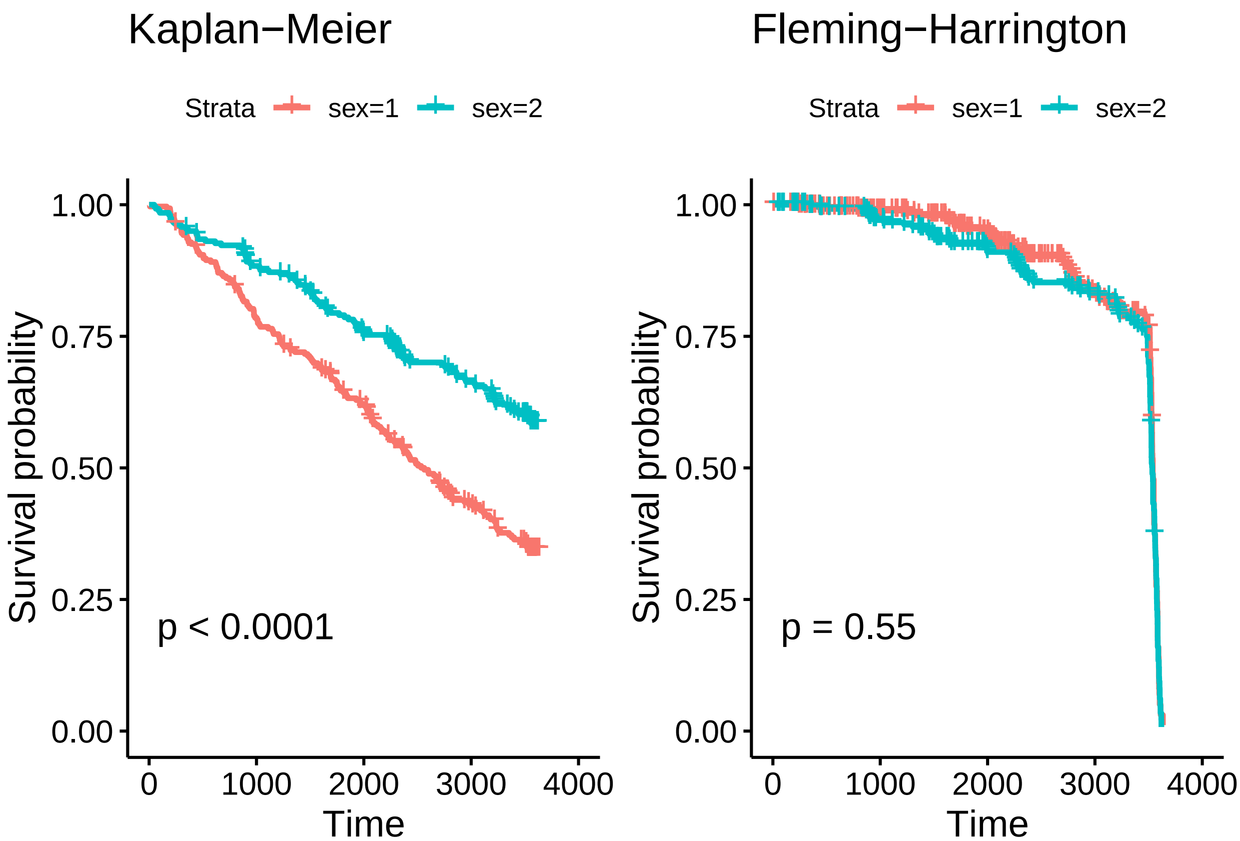
```
##           tstart tstop nsubs nlost  nrisk nevent        surv          pdf
## 0-300          0   300   260     1  259.5     25  1.00000000 0.0003211304
## 300-600      300   600   234     3  232.5     25  0.90366089 0.0003238928
## 600-900      600   900   206     4  204.0     29  0.80649305 0.0003821617
## 900-1200     900  1200   173     3  171.5     26  0.69184453 0.0003496202
## 1200-1500   1200  1500   144     7  140.5     22  0.58695848 0.0003063603
## 1500-1800   1500  1800   115     8  111.0     29  0.49505039 0.0004311250
## 1800-2100   1800  2100    78     9   73.5     26  0.36571290 0.0004312261
## 2100-2400   2100  2400    43    14   36.0     26  0.23634507 0.0005689789
## 2400-2700   2400  2700     3     1    2.5     16  0.06565141 0.0014005634
## 2700-3000   2700  3000   -14    13  -20.5     19 -0.35451761 0.0010952576
## 3000-Inf    3000   Inf   -46   214 -153.0     35 -0.68309490           NA
##                  hazard    se.surv       se.pdf    se.hazard
## 0-300      0.0003373819 0.00000000 6.105400e-05 6.738992e-05
## 300-600    0.0003787879 0.01831620 6.154794e-05 7.563519e-05
## 600-900    0.0005101143 0.02458190 6.675243e-05 9.444814e-05
## 900-1200   0.0005467928 0.02887035 6.481848e-05 1.068736e-04
## 1200-1500  0.0005662806 0.03096618 6.212426e-05 1.202951e-04
## 1500-1800  0.0010017271 0.03171679 7.414652e-05 1.839042e-04
## 1800-2100  0.0014325069 0.03122682 7.731692e-05 2.743754e-04
## 2100-2400  0.0037681159 0.02869232 9.071912e-05 6.096225e-04
## 2400-2700 -0.0096969697 0.01935995          NaN          NaN
## 2700-3000 -0.0021111111        NaN          NaN 4.593974e-04
## 3000-Inf             NA        NaN           NA           NA
```

KM and FH

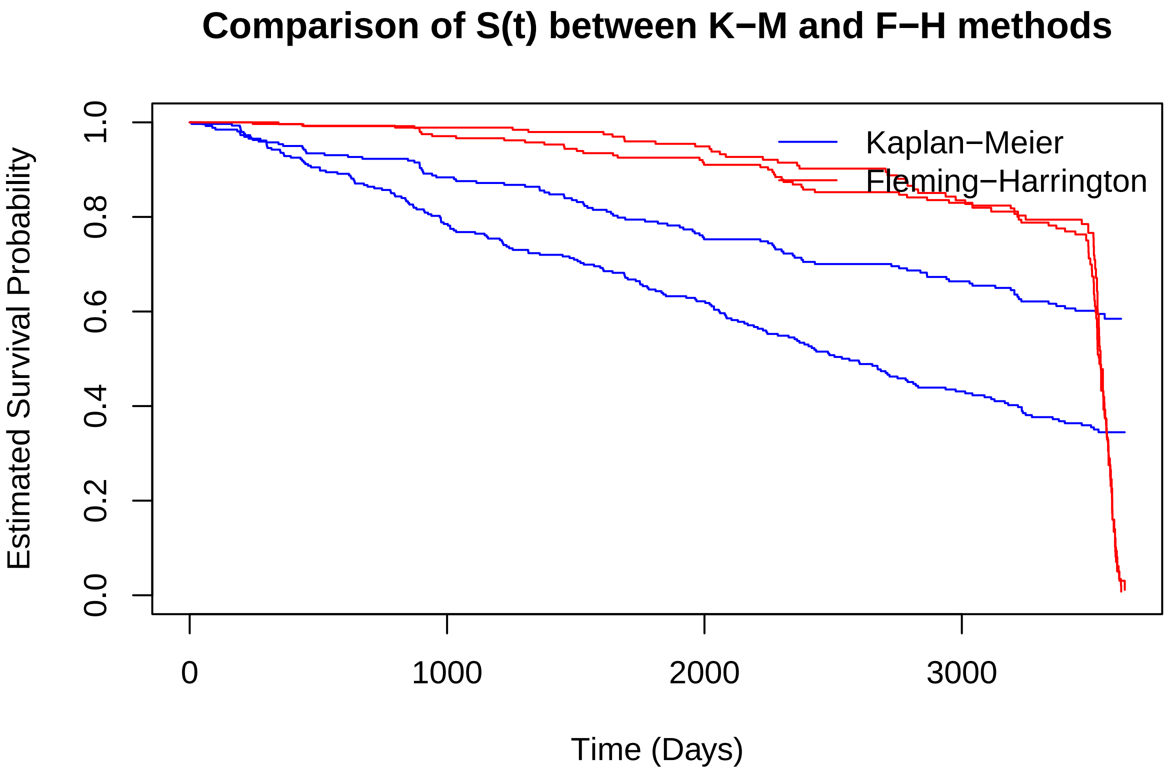
```
fit <- brvSplit%>%
  survfit(Surv(brvSplit$dox-brvSplit$doe, fail==1) ~ brv, data = .)

fit2 <- brvSplit %>%
  survfit(Surv(brvSplit$dox-brvSplit$doe, fail==0) ~ brv, data = ., type = "fleming")

splots <- list()

splots[[1]] <- ggsurvplot(fit, data = brvSplit, pval = TRUE, title = "Kaplan-Meier")
splots[[2]] <- ggsurvplot(fit2, data = brvSplit, pval = TRUE, title = "Fleming-Harrington")

arrange_ggsurvplots(splots, print = TRUE,
  ncol = 2, nrow = 1)
```



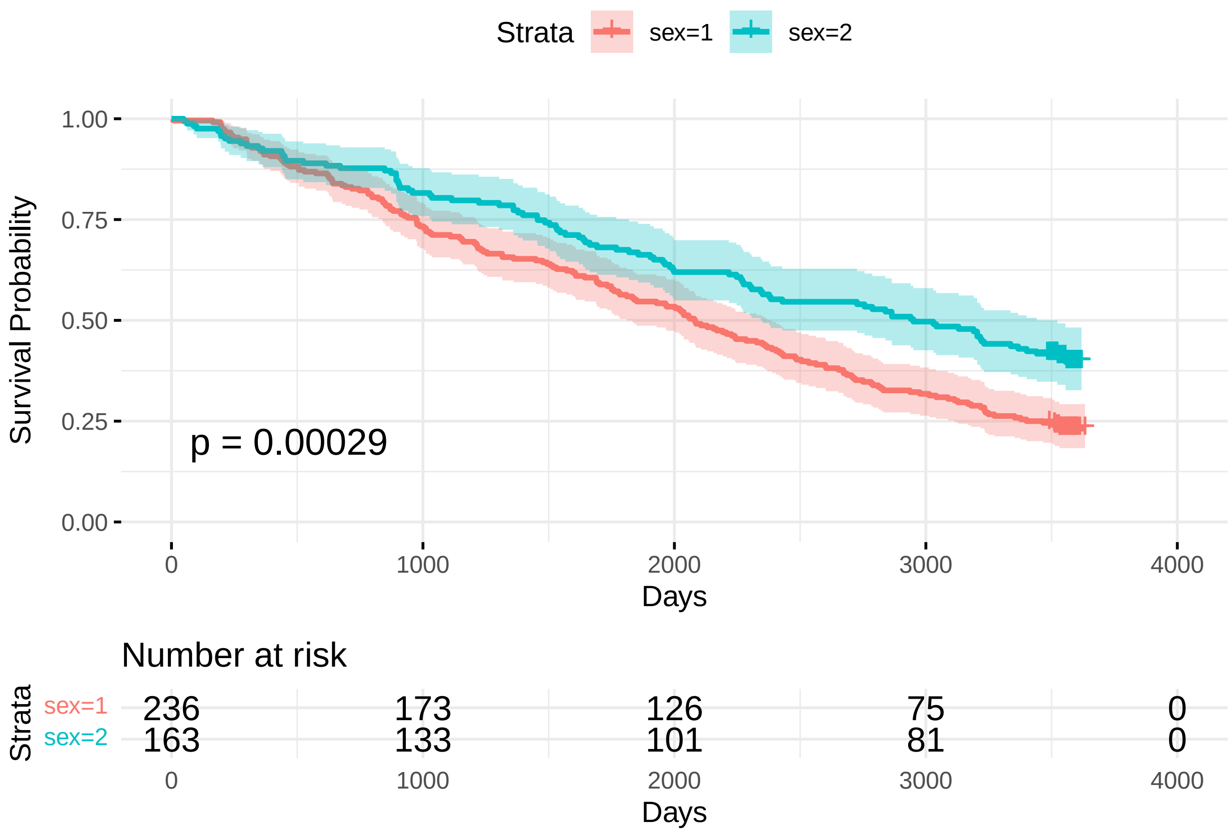

```
fit3 <- brvSplit%>%
  survfit(Surv(brvSplit$dox-brvSplit$doe, fail==1) ~ sex, data = .)

fit4 <- brvSplit %>%
  survfit(Surv(brvSplit$dox-brvSplit$doe, fail==0) ~ sex, data = ., type = "fleming")

splots <- list()

splots[[1]] <- ggsurvplot(fit3, data = brvSplit, pval = TRUE, title = "Kaplan-Meier")
splots[[2]] <- ggsurvplot(fit4, data = brvSplit, pval = TRUE, title = "Fleming-Harrington")

arrange_ggsurvplots(splots, print = TRUE,
  ncol = 2, nrow = 1)
```



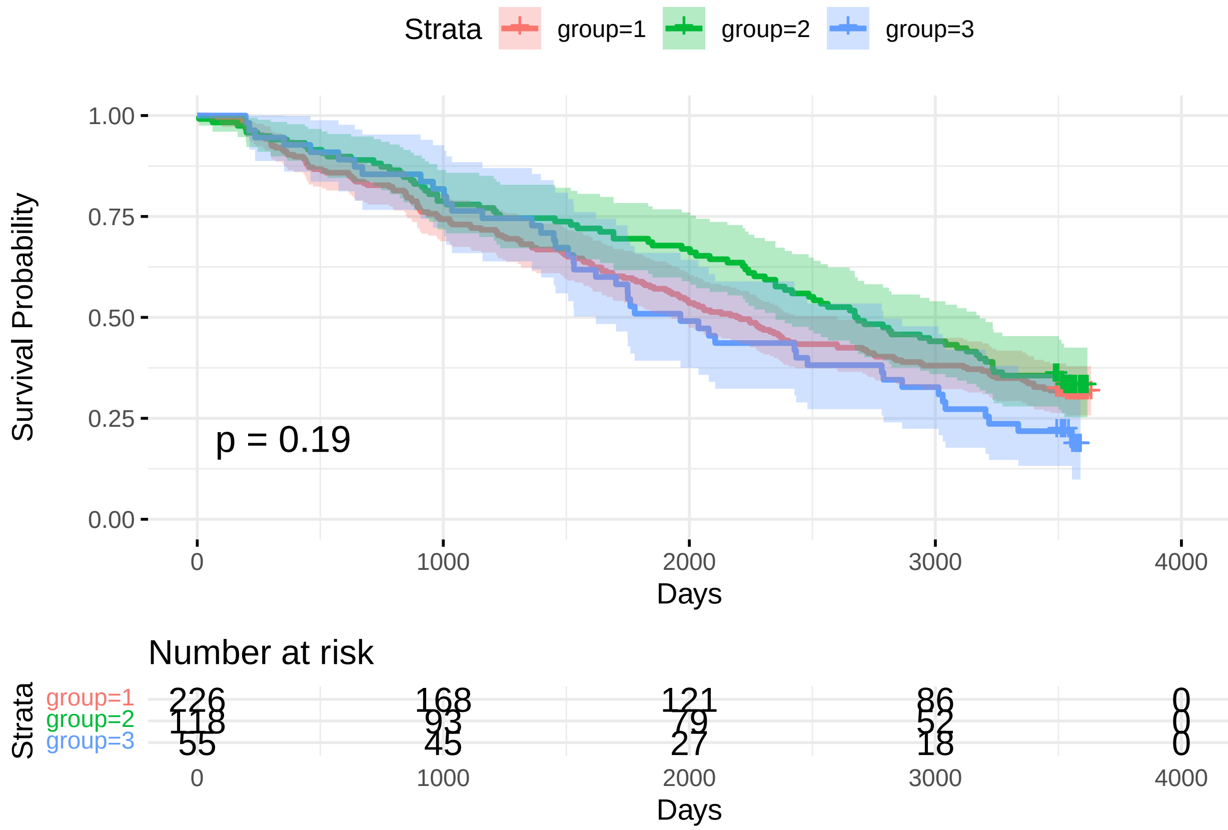

```r
plot(fit3, conf.int = FALSE, col = "blue",
     xlab = "Time (Days)", ylab = "Estimated Survival Probability",
     main = "Comparison of S(t) between K-M and F-H methods")
lines(fit4, conf.int = FALSE, col = "red")
legend("topright", c("Kaplan-Meier", "Fleming-Harrington"),
       col = c("blue", "red"), lty = 1, bty = "n")
```


Comparison of S(t) between K−M and F−H methods
Kaplan−Meier
Fleming−Harrington
Estimated Survival Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
1000
2000
3000
Time (Days)

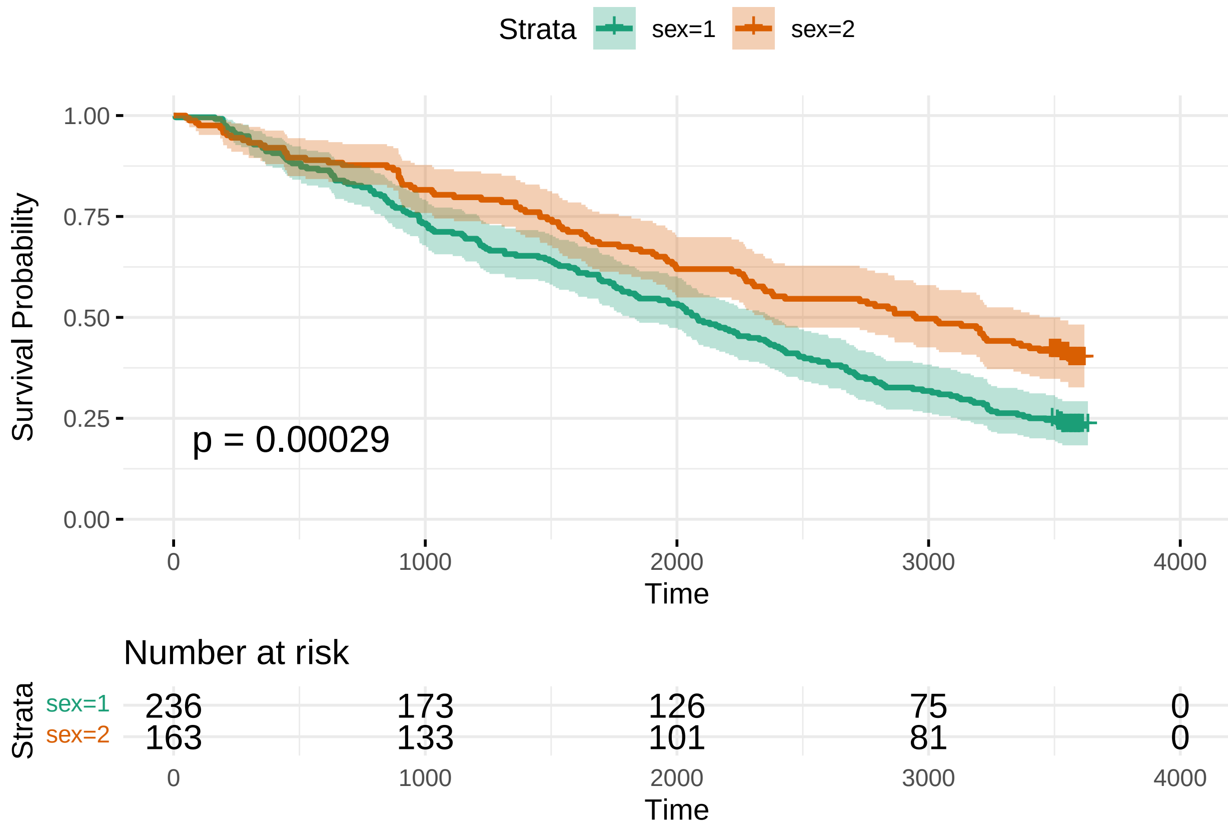
```r
surv_obj <- Surv(time = brv$dox-brv$doe, event = brv$fail)

km_fit1 <- survfit(surv_obj ~ brv$sex)
ggsurvplot(km_fit1, data= brv,
           pval = TRUE,
           conf.int = TRUE,
           risk.table = TRUE,
           ggtheme = theme_minimal(),
           palette = "Dark",
           main = "Kaplan-Meier Survival Curve",
           xlab = "Days",
           ylab = "Survival Probability")
```




```r
surv_obj <- Surv(time = brv$dox-brv$doe, event = brv$fail)

km_fit1 <- survfit(surv_obj ~ brv$group)
ggsurvplot(km_fit1, data= brv,
           pval = TRUE,
           conf.int = TRUE,
           risk.table = TRUE,
           ggtheme = theme_minimal(),
           palette = "Dark",
           main = "Kaplan-Meier Survival Curve",
           xlab = "Days",
           ylab = "Survival Probability")
```




```
km_fit2 <- survfit(surv_obj ~brv$sex)


ggsurvplot(km_fit2, data=brv,
           pval = TRUE,
           conf.int = TRUE,
           risk.table = TRUE,
           ggtheme = theme_minimal(),
           palette = "Dark2",
           main = "Kaplan-Meier Survival Curve",
           xlab = "Time",
           ylab = "Survival Probability")
```




```
## Call:
## survdiff(formula = surv_obj ~ group, data = brv)
##
##            N Observed Expected (O-E)^2/E (O-E)^2/V
## group=1 226      155    153.2    0.0212    0.0472
## group=2 118       79     89.5    1.2217    1.8051
## group=3  55       44     35.3    2.1183    2.4336
##
##  Chisq= 3.4  on 2 degrees of freedom, p= 0.2
```

Log-rank test (death as event) comparing group

```
surv_obj1 <- Surv(time = brv$dox-brv$doe, event = brv$fail)

log_rank_test <- survdiff(surv_obj1 ~ group, data = brv)

print(log_rank_test)
```

```
## Call:
## survdiff(formula = surv_obj1 ~ group, data = brv)
##
##            N Observed Expected (O-E)^2/E (O-E)^2/V
## group=1 226      155    153.2    0.0212    0.0472
## group=2 118       79     89.5    1.2217    1.8051
## group=3  55       44     35.3    2.1183    2.4336
##
##  Chisq= 3.4  on 2 degrees of freedom, p= 0.2
```

```r
surv_obj1 <- Surv(time = brv$dox-brv$doe, event = brv$fail)

log_rank_test2 <- survdiff(surv_obj1 ~ sex, data = brv)

print(log_rank_test2)
```

```
## Call:
## survdiff(formula = surv_obj1 ~ sex, data = brv)
##
##          N Observed Expected (O-E)^2/E (O-E)^2/V
## sex=1 236      181      151      5.95      13.1
## sex=2 163       97      127      7.08      13.1
##
##  Chisq= 13.1  on 1 degrees of freedom, p= 3e-04
```

```r
# Creating the survival object
surv_obj <- Surv(time = brv$dox - brv$doe, event = brv$fail)

# Fit Cox model (specify variables or use '.' for all variables)
cox_model <- coxph(surv_obj ~ ., data = brv)
```

```
## Warning in coxph.fit(X, Y, istrat, offset, init, control, weights = weights, :
## Ran out of iterations and did not converge

## Warning in coxph.fit(X, Y, istrat, offset, init, control, weights = weights, :
## one or more coefficients may be infinite
```

```r
summary(cox_model)
```

```
## Call:
## coxph(formula = surv_obj ~ ., data = brv)
##
##   n= 399, number of events= 278
##
##              coef  exp(coef)   se(coef)        z Pr(>|z|)
## id      2.802e-06  1.000e+00  1.184e-05    0.237    0.813
## couple -2.653e-03  9.974e-01  1.645e-03   -1.613    0.107
## dob     4.051e-05  1.000e+00  8.990e-05    0.451    0.652
## doe     3.118e-01  1.366e+00  2.607e-03  119.608   <2e-16 ***
## dox    -3.110e-01  7.327e-01  2.602e-03 -119.551   <2e-16 ***
## dosp    5.955e-06  1.000e+00  4.813e-05    0.124    0.902
## fail    6.643e+00  7.671e+02  5.758e+00    1.154    0.249
## group  -8.489e-02  9.186e-01  1.577e-01   -0.538    0.590
## disab   2.197e-02  1.022e+00  1.162e-01    0.189    0.850
## health -8.354e-03  9.917e-01  2.094e-01   -0.040    0.968
## sex     7.317e-02  1.076e+00  2.562e-01    0.286    0.775
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##        exp(coef) exp(-coef) lower .95 upper .95
## id        1.0000   0.999997  0.999980 1.000e+00
## couple    0.9974   1.002656  0.994140 1.001e+00
## dob       1.0000   0.999959  0.999864 1.000e+00
## doe       1.3658   0.732151  1.358878 1.373e+00
## dox       0.7327   1.364817  0.728972 7.364e-01
## dosp      1.0000   0.999994  0.999912 1.000e+00
```

```
## fail    767.0831   0.001304  0.009628 6.111e+07
## group     0.9186   1.088598  0.674428 1.251e+00
## disab     1.0222   0.978270  0.813937 1.284e+00
## health    0.9917   1.008389  0.657892 1.495e+00
## sex       1.0759   0.929441  0.651162 1.778e+00
##
## Concordance= 1  (se = 0 )
## Likelihood ratio test= 2947  on 11 df,   p=<2e-16
## Wald test            = 28603  on 11 df,   p=<2e-16
## Score (logrank) test = 906.5  on 11 df,   p=<2e-16
```

```r
# Check proportional hazards assumption
cox.zph(cox_model)
```

```
##        chisq df   p
## id       NaN  1 NaN
## couple   NaN  1 NaN
## dob      NaN  1 NaN
## doe      NaN  1 NaN
## dox      NaN  1 NaN
## dosp     NaN  1 NaN
## fail     NaN  1 NaN
## group    NaN  1 NaN
## disab    NaN  1 NaN
## health   NaN  1 NaN
## sex      NaN  1 NaN
## GLOBAL   NaN 11 NaN
```

Kaplan-Meier and Fleming-Harrington model

For nonparametric estimator, Kaplan-Meier(KM) model and Fleming-Harrington(FH) model were used to measure the fraction of subjects living for a certain amount of time after treatment with the stratify of sex.[3]

The Kaplan-Meier estimator

$$\hat{S}_K(t) = \begin{cases} 1 & \text{if } t < t_1 \\ \prod_{t_i \le t}[1 - \frac{d_i}{n_i}] & \text{if } t \ge t_1 \end{cases}$$

note: $d_i = \#\ of\ failure\ at\ time\ t_i$, $n_i = \#\ at\ risk\ at\ t_i^-$, $c_i = \#\ censored\ during\ the\ interval\ [t_i, t_{i+1}]$

The Fleming-Harrington estimator

$$\hat{S}_F(t) = \begin{cases} 1 & \text{if } t < t_1 \\ \prod_{t_i \le t} exp[-\frac{d_i}{n_i}] & \text{if } t \ge t_1 \end{cases}$$