Survival Analysis1

2023-11-06

Packages

Consider the Mayo Clinic Lung Cancer Data in R package survival : data(lung)

or data(cancer): including the variables

```
   inst:       Institution code

   time:       Survival time in days

   status:     censoring status 1=censored, 2=dead

   age:        Age in years

   sex:        Male=1 Female=2, etc.
```

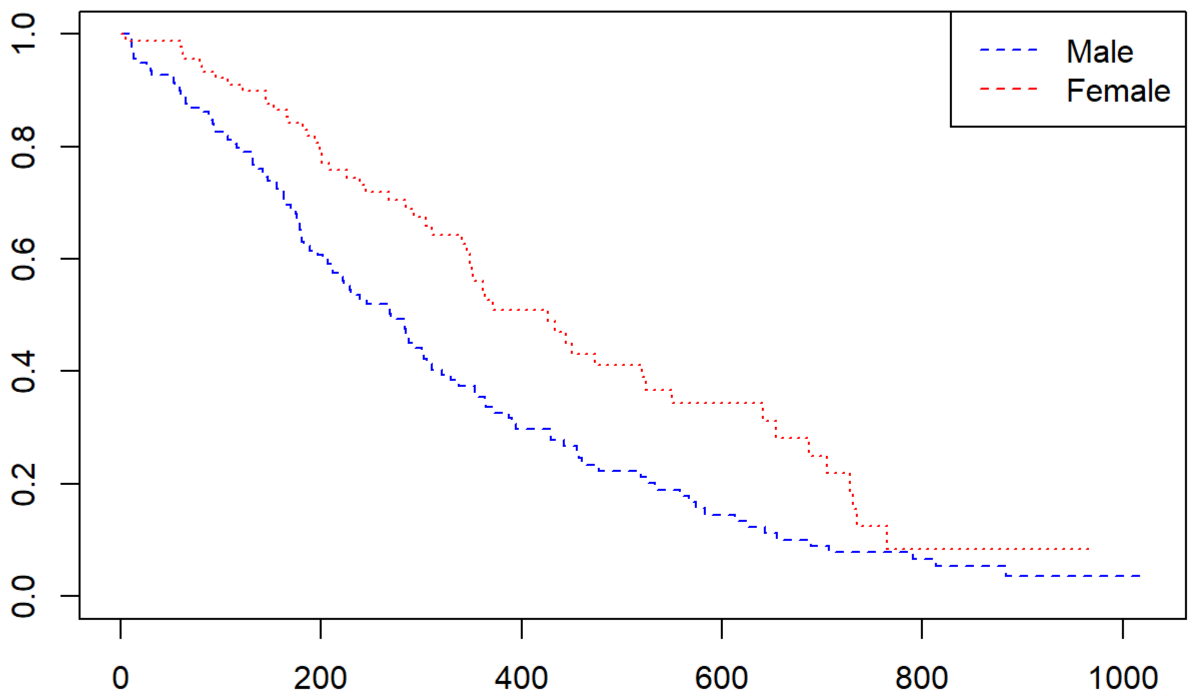
Dataset

```
library(survival)
data(cancer)
```

Q1(a)

Estimate and plot the survival curves for time by SEX using the following methods: a.Kaplan-Meier

```
fit <- survfit(Surv(time,status)~sex,data=cancer)
plot(fit,lty=2:3,col = c("blue", "red"))
legend("topright", legend = c("Male", "Female"), lty = c(2, 2), col = c("blue", "red"))
```



Before two survival curves intersects around time 780, female have the longer survival time. After the intersection time, it reversed.

Q1(b)

Estimate and plot the survival curves for time by SEX using the following methods: b.Fleming-Harrington

```
#if (!require("BiocManager", quietly = TRUE))
#    install.packages("BiocManager")

#BiocManager::install("Icens")

library(BiocManager)
```

```
## Warning: package 'BiocManager' was built under R version 4.2.3
```

```
## Bioconductor version '3.16' is out-of-date; the current release version '3.18'
##   is available with R version '4.3'; see https://bioconductor.org/install
```

```
library(Icens)
library(FHtest)
```

```
## Warning: package 'FHtest' was built under R version 4.2.3
```

```
## Loading required package: interval
```

```
## Warning: package 'interval' was built under R version 4.2.3
```

```
## Loading required package: perm
```

```
## Warning: package 'perm' was built under R version 4.2.3
```

```
## Loading required package: MLEcens
```

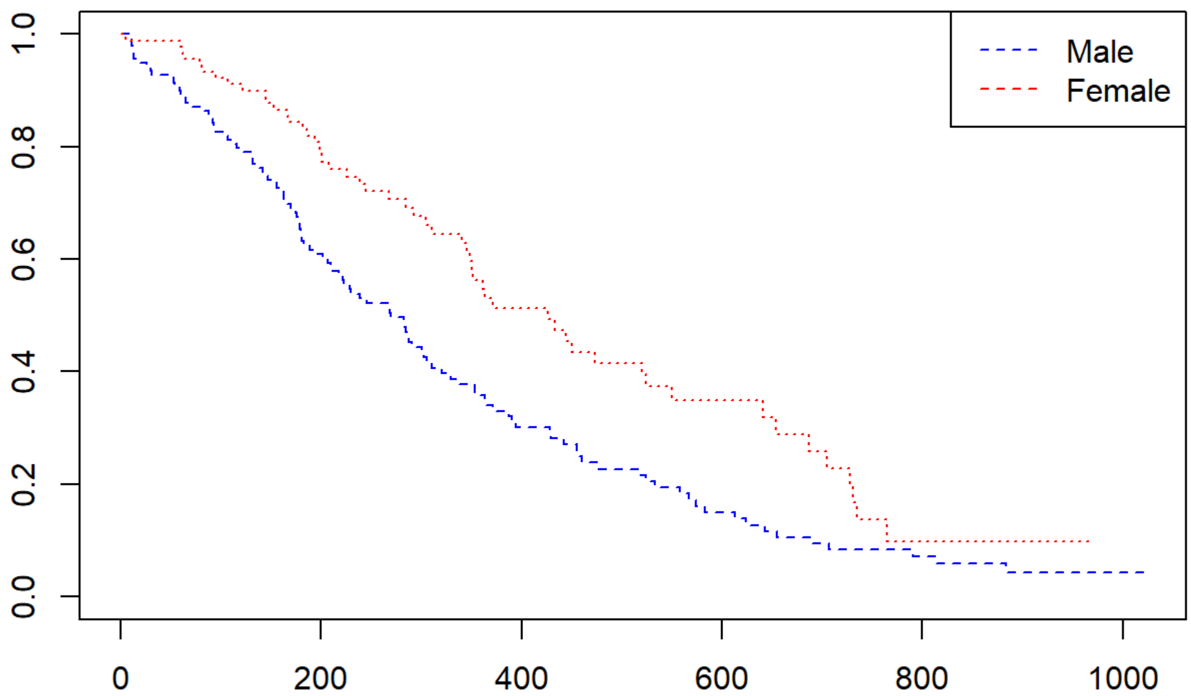
```
## Depends on Icens package available on bioconductor.
## To install use for example:
## install.packages('BiocManager')
## BiocManager::install('Icens')
```

```
## Loading required package: KMsurv
```

```
fit2 <- FHtestics(Surv(time,status)~sex,data=cancer)
fit2
```

```
##
##  Two-sample test for interval-censored data
##
## Parameters: rho=0, lambda=0
## Distribution: score vector approach
##
## Data: Surv(time, status) by sex
##
##         N   O-E
## sex=1 138  20.5
## sex=2  90 -20.5
##
## Statistic Z= -3.2, p-value= 0.00125
## Alternative hypothesis: survival functions not equal
```

```
fit2  <- survfit(Surv(time,status)~sex,data=cancer, type = "fleming-harrington")
plot(fit2,lty=2:3,col = c("blue", "red"))
legend("topright", legend = c("Male", "Female"), lty = c(2, 2), col = c("blue", "red"))
```



Different from kaplan-meier, there is no intersection around time 780, because it’s more sensitive to late differences in survival than other tests.

Q2

2.For each case in 1, estimate the median survival time, using the estimated survival curves.

```
summary(fit)
```

```
## Call: survfit(formula = Surv(time, status) ~ sex, data = cancer)
##
##                 sex=1
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    11    138       3   0.9783  0.0124       0.9542        1.000
##    12    135       1   0.9710  0.0143       0.9434        0.999
##    13    134       2   0.9565  0.0174       0.9231        0.991
##    15    132       1   0.9493  0.0187       0.9134        0.987
##    26    131       1   0.9420  0.0199       0.9038        0.982
##    30    130       1   0.9348  0.0210       0.8945        0.977
##    31    129       1   0.9275  0.0221       0.8853        0.972
##    53    128       2   0.9130  0.0240       0.8672        0.961
##    54    126       1   0.9058  0.0249       0.8583        0.956
##    59    125       1   0.8986  0.0257       0.8496        0.950
##    60    124       1   0.8913  0.0265       0.8409        0.945
##    65    123       2   0.8768  0.0280       0.8237        0.933
##    71    121       1   0.8696  0.0287       0.8152        0.928
##    81    120       1   0.8623  0.0293       0.8067        0.922
##    88    119       2   0.8478  0.0306       0.7900        0.910
##    92    117       1   0.8406  0.0312       0.7817        0.904
##    93    116       1   0.8333  0.0317       0.7734        0.898
##    95    115       1   0.8261  0.0323       0.7652        0.892
##   105    114       1   0.8188  0.0328       0.7570        0.886
##   107    113       1   0.8116  0.0333       0.7489        0.880
##   110    112       1   0.8043  0.0338       0.7408        0.873
##   116    111       1   0.7971  0.0342       0.7328        0.867
##   118    110       1   0.7899  0.0347       0.7247        0.861
##   131    109       1   0.7826  0.0351       0.7167        0.855
##   132    108       2   0.7681  0.0359       0.7008        0.842
##   135    106       1   0.7609  0.0363       0.6929        0.835
##   142    105       1   0.7536  0.0367       0.6851        0.829
##   144    104       1   0.7464  0.0370       0.6772        0.823
##   147    103       1   0.7391  0.0374       0.6694        0.816
##   156    102       2   0.7246  0.0380       0.6538        0.803
##   163    100       3   0.7029  0.0389       0.6306        0.783
##   166     97       1   0.6957  0.0392       0.6230        0.777
##   170     96       1   0.6884  0.0394       0.6153        0.770
##   175     94       1   0.6811  0.0397       0.6076        0.763
##   176     93       1   0.6738  0.0399       0.5999        0.757
##   177     92       1   0.6664  0.0402       0.5922        0.750
##   179     91       2   0.6518  0.0406       0.5769        0.736
##   180     89       1   0.6445  0.0408       0.5693        0.730
##   181     88       2   0.6298  0.0412       0.5541        0.716
##   183     86       1   0.6225  0.0413       0.5466        0.709
##   189     83       1   0.6150  0.0415       0.5388        0.702
##   197     80       1   0.6073  0.0417       0.5309        0.695
##   202     78       1   0.5995  0.0419       0.5228        0.687
##   207     77       1   0.5917  0.0420       0.5148        0.680
##   210     76       1   0.5839  0.0422       0.5068        0.673
##   212     75       1   0.5762  0.0424       0.4988        0.665
##   218     74       1   0.5684  0.0425       0.4909        0.658
##   222     72       1   0.5605  0.0426       0.4829        0.651
```

```
##    223     70        1   0.5525  0.0428       0.4747        0.643
##    229     67        1   0.5442  0.0429       0.4663        0.635
##    230     66        1   0.5360  0.0431       0.4579        0.627
##    239     64        1   0.5276  0.0432       0.4494        0.619
##    246     63        1   0.5192  0.0433       0.4409        0.611
##    267     61        1   0.5107  0.0434       0.4323        0.603
##    269     60        1   0.5022  0.0435       0.4238        0.595
##    270     59        1   0.4937  0.0436       0.4152        0.587
##    283     57        1   0.4850  0.0437       0.4065        0.579
##    284     56        1   0.4764  0.0438       0.3979        0.570
##    285     54        1   0.4676  0.0438       0.3891        0.562
##    286     53        1   0.4587  0.0439       0.3803        0.553
##    288     52        1   0.4499  0.0439       0.3716        0.545
##    291     51        1   0.4411  0.0439       0.3629        0.536
##    301     48        1   0.4319  0.0440       0.3538        0.527
##    303     46        1   0.4225  0.0440       0.3445        0.518
##    306     44        1   0.4129  0.0440       0.3350        0.509
##    310     43        1   0.4033  0.0441       0.3256        0.500
##    320     42        1   0.3937  0.0440       0.3162        0.490
##    329     41        1   0.3841  0.0440       0.3069        0.481
##    337     40        1   0.3745  0.0439       0.2976        0.471
##    353     39        2   0.3553  0.0437       0.2791        0.452
##    363     37        1   0.3457  0.0436       0.2700        0.443
##    364     36        1   0.3361  0.0434       0.2609        0.433
##    371     35        1   0.3265  0.0432       0.2519        0.423
##    387     34        1   0.3169  0.0430       0.2429        0.413
##    390     33        1   0.3073  0.0428       0.2339        0.404
##    394     32        1   0.2977  0.0425       0.2250        0.394
##    428     29        1   0.2874  0.0423       0.2155        0.383
##    429     28        1   0.2771  0.0420       0.2060        0.373
##    442     27        1   0.2669  0.0417       0.1965        0.362
##    455     25        1   0.2562  0.0413       0.1868        0.351
##    457     24        1   0.2455  0.0410       0.1770        0.341
##    460     22        1   0.2344  0.0406       0.1669        0.329
##    477     21        1   0.2232  0.0402       0.1569        0.318
##    519     20        1   0.2121  0.0397       0.1469        0.306
##    524     19        1   0.2009  0.0391       0.1371        0.294
##    533     18        1   0.1897  0.0385       0.1275        0.282
##    558     17        1   0.1786  0.0378       0.1179        0.270
##    567     16        1   0.1674  0.0371       0.1085        0.258
##    574     15        1   0.1562  0.0362       0.0992        0.246
##    583     14        1   0.1451  0.0353       0.0900        0.234
##    613     13        1   0.1339  0.0343       0.0810        0.221
##    624     12        1   0.1228  0.0332       0.0722        0.209
##    643     11        1   0.1116  0.0320       0.0636        0.196
##    655     10        1   0.1004  0.0307       0.0552        0.183
##    689      9        1   0.0893  0.0293       0.0470        0.170
##    707      8        1   0.0781  0.0276       0.0390        0.156
##    791      7        1   0.0670  0.0259       0.0314        0.143
##    814      5        1   0.0536  0.0239       0.0223        0.128
##    883      3        1   0.0357  0.0216       0.0109        0.117
##
```

```
##                 sex=2 
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     5     90       1   0.9889  0.0110       0.9675        1.000
##    60     89       1   0.9778  0.0155       0.9478        1.000
##    61     88       1   0.9667  0.0189       0.9303        1.000
##    62     87       1   0.9556  0.0217       0.9139        0.999
##    79     86       1   0.9444  0.0241       0.8983        0.993
##    81     85       1   0.9333  0.0263       0.8832        0.986
##    95     83       1   0.9221  0.0283       0.8683        0.979
##   107     81       1   0.9107  0.0301       0.8535        0.972
##   122     80       1   0.8993  0.0318       0.8390        0.964
##   145     79       2   0.8766  0.0349       0.8108        0.948
##   153     77       1   0.8652  0.0362       0.7970        0.939
##   166     76       1   0.8538  0.0375       0.7834        0.931
##   167     75       1   0.8424  0.0387       0.7699        0.922
##   182     71       1   0.8305  0.0399       0.7559        0.913
##   186     70       1   0.8187  0.0411       0.7420        0.903
##   194     68       1   0.8066  0.0422       0.7280        0.894
##   199     67       1   0.7946  0.0432       0.7142        0.884
##   201     66       2   0.7705  0.0452       0.6869        0.864
##   208     62       1   0.7581  0.0461       0.6729        0.854
##   226     59       1   0.7452  0.0471       0.6584        0.843
##   239     57       1   0.7322  0.0480       0.6438        0.833
##   245     54       1   0.7186  0.0490       0.6287        0.821
##   268     51       1   0.7045  0.0501       0.6129        0.810
##   285     47       1   0.6895  0.0512       0.5962        0.798
##   293     45       1   0.6742  0.0523       0.5791        0.785
##   305     43       1   0.6585  0.0534       0.5618        0.772
##   310     42       1   0.6428  0.0544       0.5447        0.759
##   340     39       1   0.6264  0.0554       0.5267        0.745
##   345     38       1   0.6099  0.0563       0.5089        0.731
##   348     37       1   0.5934  0.0572       0.4913        0.717
##   350     36       1   0.5769  0.0579       0.4739        0.702
##   351     35       1   0.5604  0.0586       0.4566        0.688
##   361     33       1   0.5434  0.0592       0.4390        0.673
##   363     32       1   0.5265  0.0597       0.4215        0.658
##   371     30       1   0.5089  0.0603       0.4035        0.642
##   426     26       1   0.4893  0.0610       0.3832        0.625
##   433     25       1   0.4698  0.0617       0.3632        0.608
##   444     24       1   0.4502  0.0621       0.3435        0.590
##   450     23       1   0.4306  0.0624       0.3241        0.572
##   473     22       1   0.4110  0.0626       0.3050        0.554
##   520     19       1   0.3894  0.0629       0.2837        0.534
##   524     18       1   0.3678  0.0630       0.2628        0.515
##   550     15       1   0.3433  0.0634       0.2390        0.493
##   641     11       1   0.3121  0.0649       0.2076        0.469
##   654     10       1   0.2808  0.0655       0.1778        0.443
##   687      9       1   0.2496  0.0652       0.1496        0.417
##   705      8       1   0.2184  0.0641       0.1229        0.388
##   728      7       1   0.1872  0.0621       0.0978        0.359
##   731      6       1   0.1560  0.0590       0.0743        0.328
```

```
##   735      5       1   0.1248  0.0549       0.0527        0.295
##   765      3       1   0.0832  0.0499       0.0257        0.270
```

```
summary(fit2)
```

```
## Call: survfit(formula = Surv(time, status) ~ sex, data = cancer, type = "fleming-harrington")
##
##                 sex=1
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    11    138       3   0.9785  0.0123       0.9547        1.000
##    12    135       1   0.9713  0.0142       0.9439        0.999
##    13    134       2   0.9569  0.0172       0.9237        0.991
##    15    132       1   0.9497  0.0185       0.9140        0.987
##    26    131       1   0.9424  0.0198       0.9045        0.982
##    30    130       1   0.9352  0.0209       0.8952        0.977
##    31    129       1   0.9280  0.0219       0.8860        0.972
##    53    128       2   0.9136  0.0238       0.8681        0.962
##    54    126       1   0.9064  0.0247       0.8592        0.956
##    59    125       1   0.8992  0.0256       0.8504        0.951
##    60    124       1   0.8919  0.0264       0.8418        0.945
##    65    123       2   0.8776  0.0278       0.8247        0.934
##    71    121       1   0.8703  0.0285       0.8162        0.928
##    81    120       1   0.8631  0.0292       0.8078        0.922
##    88    119       2   0.8487  0.0304       0.7912        0.910
##    92    117       1   0.8415  0.0310       0.7829        0.905
##    93    116       1   0.8343  0.0316       0.7747        0.898
##    95    115       1   0.8271  0.0321       0.7665        0.892
##   105    114       1   0.8198  0.0326       0.7583        0.886
##   107    113       1   0.8126  0.0331       0.7502        0.880
##   110    112       1   0.8054  0.0336       0.7421        0.874
##   116    111       1   0.7982  0.0341       0.7341        0.868
##   118    110       1   0.7909  0.0345       0.7261        0.862
##   131    109       1   0.7837  0.0350       0.7181        0.855
##   132    108       2   0.7693  0.0358       0.7023        0.843
##   135    106       1   0.7621  0.0362       0.6945        0.836
##   142    105       1   0.7549  0.0365       0.6866        0.830
##   144    104       1   0.7477  0.0369       0.6788        0.824
##   147    103       1   0.7404  0.0372       0.6710        0.817
##   156    102       2   0.7261  0.0379       0.6555        0.804
##   163    100       3   0.7046  0.0387       0.6327        0.785
##   166     97       1   0.6974  0.0390       0.6250        0.778
##   170     96       1   0.6902  0.0393       0.6174        0.772
##   175     94       1   0.6829  0.0395       0.6096        0.765
##   176     93       1   0.6755  0.0398       0.6020        0.758
##   177     92       1   0.6682  0.0400       0.5943        0.751
##   179     91       2   0.6537  0.0404       0.5791        0.738
##   180     89       1   0.6464  0.0406       0.5715        0.731
##   181     88       2   0.6319  0.0410       0.5565        0.718
##   183     86       1   0.6246  0.0412       0.5489        0.711
##   189     83       1   0.6171  0.0413       0.5412        0.704
##   197     80       1   0.6094  0.0415       0.5332        0.697
##   202     78       1   0.6017  0.0417       0.5252        0.689
##   207     77       1   0.5939  0.0419       0.5172        0.682
##   210     76       1   0.5861  0.0421       0.5092        0.675
##   212     75       1   0.5784  0.0422       0.5013        0.667
##   218     74       1   0.5706  0.0424       0.4934        0.660
##   222     72       1   0.5628  0.0425       0.4853        0.653
```

```
##    223     70        1   0.5548  0.0426       0.4772        0.645
##    229     67        1   0.5466  0.0428       0.4688        0.637
##    230     66        1   0.5383  0.0429       0.4604        0.629
##    239     64        1   0.5300  0.0431       0.4519        0.621
##    246     63        1   0.5216  0.0432       0.4435        0.614
##    267     61        1   0.5132  0.0433       0.4349        0.605
##    269     60        1   0.5047  0.0434       0.4264        0.597
##    270     59        1   0.4962  0.0435       0.4178        0.589
##    283     57        1   0.4876  0.0436       0.4092        0.581
##    284     56        1   0.4789  0.0437       0.4005        0.573
##    285     54        1   0.4701  0.0438       0.3918        0.564
##    286     53        1   0.4614  0.0438       0.3830        0.556
##    288     52        1   0.4526  0.0438       0.3743        0.547
##    291     51        1   0.4438  0.0439       0.3656        0.539
##    301     48        1   0.4346  0.0439       0.3566        0.530
##    303     46        1   0.4253  0.0439       0.3473        0.521
##    306     44        1   0.4157  0.0440       0.3379        0.512
##    310     43        1   0.4062  0.0440       0.3285        0.502
##    320     42        1   0.3966  0.0440       0.3191        0.493
##    329     41        1   0.3871  0.0440       0.3098        0.484
##    337     40        1   0.3775  0.0439       0.3006        0.474
##    353     39        2   0.3586  0.0437       0.2825        0.455
##    363     37        1   0.3491  0.0436       0.2733        0.446
##    364     36        1   0.3395  0.0434       0.2643        0.436
##    371     35        1   0.3299  0.0432       0.2552        0.427
##    387     34        1   0.3204  0.0430       0.2463        0.417
##    390     33        1   0.3108  0.0428       0.2373        0.407
##    394     32        1   0.3013  0.0425       0.2285        0.397
##    428     29        1   0.2910  0.0423       0.2189        0.387
##    429     28        1   0.2808  0.0420       0.2095        0.377
##    442     27        1   0.2706  0.0417       0.2001        0.366
##    455     25        1   0.2600  0.0414       0.1903        0.355
##    457     24        1   0.2494  0.0410       0.1806        0.344
##    460     22        1   0.2383  0.0407       0.1705        0.333
##    477     21        1   0.2272  0.0403       0.1605        0.322
##    519     20        1   0.2162  0.0398       0.1507        0.310
##    524     19        1   0.2051  0.0393       0.1409        0.299
##    533     18        1   0.1940  0.0387       0.1312        0.287
##    558     17        1   0.1829  0.0380       0.1217        0.275
##    567     16        1   0.1718  0.0373       0.1123        0.263
##    574     15        1   0.1607  0.0365       0.1030        0.251
##    583     14        1   0.1497  0.0356       0.0939        0.239
##    613     13        1   0.1386  0.0347       0.0849        0.226
##    624     12        1   0.1275  0.0336       0.0760        0.214
##    643     11        1   0.1164  0.0325       0.0674        0.201
##    655     10        1   0.1053  0.0312       0.0589        0.188
##    689      9        1   0.0943  0.0298       0.0507        0.175
##    707      8        1   0.0832  0.0283       0.0427        0.162
##    791      7        1   0.0721  0.0266       0.0350        0.149
##    814      5        1   0.0590  0.0248       0.0259        0.134
##    883      3        1   0.0423  0.0227       0.0148        0.121
##
```

```
##                  sex=2
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     5     90       1   0.9890  0.0110       0.9676        1.000
##    60     89       1   0.9779  0.0155       0.9481        1.000
##    61     88       1   0.9669  0.0188       0.9307        1.000
##    62     87       1   0.9558  0.0216       0.9144        0.999
##    79     86       1   0.9448  0.0240       0.8988        0.993
##    81     85       1   0.9337  0.0262       0.8838        0.986
##    95     83       1   0.9225  0.0281       0.8690        0.979
##   107     81       1   0.9112  0.0300       0.8543        0.972
##   122     80       1   0.8999  0.0317       0.8399        0.964
##   145     79       2   0.8774  0.0346       0.8121        0.948
##   153     77       1   0.8661  0.0360       0.7983        0.940
##   166     76       1   0.8547  0.0373       0.7847        0.931
##   167     75       1   0.8434  0.0385       0.7713        0.922
##   182     71       1   0.8316  0.0397       0.7574        0.913
##   186     70       1   0.8198  0.0408       0.7436        0.904
##   194     68       1   0.8079  0.0420       0.7297        0.894
##   199     67       1   0.7959  0.0430       0.7159        0.885
##   201     66       2   0.7721  0.0449       0.6890        0.865
##   208     62       1   0.7598  0.0458       0.6751        0.855
##   226     59       1   0.7470  0.0468       0.6607        0.845
##   239     57       1   0.7340  0.0478       0.6461        0.834
##   245     54       1   0.7206  0.0487       0.6311        0.823
##   268     51       1   0.7066  0.0498       0.6155        0.811
##   285     47       1   0.6917  0.0509       0.5988        0.799
##   293     45       1   0.6765  0.0520       0.5819        0.786
##   305     43       1   0.6609  0.0531       0.5647        0.774
##   310     42       1   0.6454  0.0541       0.5477        0.761
##   340     39       1   0.6291  0.0551       0.5298        0.747
##   345     38       1   0.6127  0.0560       0.5122        0.733
##   348     37       1   0.5964  0.0569       0.4947        0.719
##   350     36       1   0.5800  0.0576       0.4774        0.705
##   351     35       1   0.5637  0.0583       0.4603        0.690
##   361     33       1   0.5469  0.0589       0.4428        0.675
##   363     32       1   0.5300  0.0594       0.4254        0.660
##   371     30       1   0.5127  0.0600       0.4076        0.645
##   426     26       1   0.4933  0.0608       0.3875        0.628
##   433     25       1   0.4740  0.0614       0.3677        0.611
##   444     24       1   0.4546  0.0618       0.3482        0.594
##   450     23       1   0.4353  0.0622       0.3290        0.576
##   473     22       1   0.4160  0.0623       0.3101        0.558
##   520     19       1   0.3946  0.0627       0.2891        0.539
##   524     18       1   0.3733  0.0628       0.2684        0.519
##   550     15       1   0.3492  0.0632       0.2449        0.498
##   641     11       1   0.3189  0.0646       0.2144        0.474
##   654     10       1   0.2885  0.0652       0.1853        0.449
##   687      9       1   0.2582  0.0650       0.1576        0.423
##   705      8       1   0.2279  0.0640       0.1313        0.395
##   728      7       1   0.1975  0.0623       0.1065        0.366
##   731      6       1   0.1672  0.0596       0.0831        0.336
```

```
##    735      5       1   0.1369  0.0560       0.0614        0.305
##    765      3       1   0.0981  0.0517       0.0349        0.276
```

a. Between time 296-270 for sex1(male) and between 371-426 for sex2(female).
b. Between time 296-270 for sex1(male) and between 371-426 for sex2(female).

Q3

3.Using a log-rank test, compare the survival distributions for Male and Female

```
survdiff(Surv(time,status)~sex, data=cancer, rho=0)
```

```
## Call:
## survdiff(formula = Surv(time, status) ~ sex, data = cancer, rho = 0)
##
##         N Observed Expected (O-E)^2/E (O-E)^2/V
## sex=1 138      112     91.6      4.55      10.3
## sex=2  90       53     73.4      5.68      10.3
##
##  Chisq= 10.3  on 1 degrees of freedom, p= 0.001
```

The Chisq stats have the p-value as 0.001 reject the null. In other words, we have sufficient evidence to say that there is a statistically significant difference in survival between female and male groups.