Survival Analysis of Mortality of Adjuvant Chemotherapy for Colon Cancer

Yijia Jiang, Ziyan Xu

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1. Data Tidy

Recall that there are two records for each patient indicated by the event type (etype) variable, where etype == 1 refers to the event of a recurrence and etype == 2 indicates death. In order to answer our first research question, which is to study the time until death, we must create a marginal model by subsetting the colon data to only include the event of mortality.

```
# import the dataset from survival package
colon <- survival::colon

# tidy mortality dataset
colon.death <- colon %>%
  dplyr::select(-id, -study, -nodes) %>%
  drop_na() %>%
  mutate(rx = as.factor(as.numeric(rx)),
         sex = as.factor(sex),
         obstruct = as.factor(obstruct),
         perfor = as.factor(perfor),
         adhere = as.factor(adhere),
         differ = as.factor(differ),
         extent = as.factor(extent),
         surg = as.factor(surg),
         node4 =as.factor(node4)) %>%
  subset(etype == 2)
```

2. Kaplan-Meier Survival Estimate

```
death.fit <- survfit(Surv(time,status) ~ rx, data = colon.death)
options(max.print = 10000)
print(summary(death.fit))
```

```
## Call: survfit(formula = Surv(time, status) ~ rx, data = colon.death)
##
```

```
##                 rx=1
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##   113    308       1    0.997 0.00324        0.990        1.000
##   125    307       1    0.994 0.00458        0.985        1.000
##   145    306       1    0.990 0.00560        0.979        1.000
##   164    305       1    0.987 0.00645        0.974        1.000
##   166    304       1    0.984 0.00720        0.970        0.998
##   187    303       1    0.981 0.00788        0.965        0.996
##   201    302       1    0.977 0.00849        0.961        0.994
##   208    301       1    0.974 0.00906        0.956        0.992
##   215    300       1    0.971 0.00960        0.952        0.990
##   218    299       1    0.968 0.01010        0.948        0.988
##   238    298       1    0.964 0.01057        0.944        0.985
##   241    297       1    0.961 0.01103        0.940        0.983
##   242    296       1    0.958 0.01146        0.936        0.981
##   253    295       1    0.955 0.01187        0.932        0.978
##   259    294       2    0.948 0.01265        0.924        0.973
##   264    292       1    0.945 0.01301        0.920        0.971
##   275    291       1    0.942 0.01337        0.916        0.968
##   289    290       1    0.938 0.01371        0.912        0.966
##   311    289       1    0.935 0.01404        0.908        0.963
##   313    288       1    0.932 0.01436        0.904        0.960
##   322    287       1    0.929 0.01467        0.900        0.958
##   331    286       1    0.925 0.01498        0.896        0.955
##   365    285       1    0.922 0.01527        0.893        0.953
##   372    284       1    0.919 0.01556        0.889        0.950
##   381    283       1    0.916 0.01584        0.885        0.947
##   384    282       2    0.909 0.01638        0.878        0.942
##   390    280       1    0.906 0.01664        0.874        0.939
##   409    279       1    0.903 0.01689        0.870        0.936
##   411    278       1    0.899 0.01714        0.866        0.934
##   413    277       2    0.893 0.01762        0.859        0.928
##   417    275       1    0.890 0.01786        0.855        0.925
##   421    274       1    0.886 0.01808        0.852        0.923
##   433    273       1    0.883 0.01831        0.848        0.920
##   437    272       1    0.880 0.01853        0.844        0.917
##   438    271       1    0.877 0.01874        0.841        0.914
##   459    269       1    0.873 0.01895        0.837        0.911
##   462    268       1    0.870 0.01916        0.833        0.908
##   464    267       1    0.867 0.01936        0.830        0.906
##   465    266       2    0.860 0.01976        0.822        0.900
##   474    264       1    0.857 0.01995        0.819        0.897
##   485    263       1    0.854 0.02014        0.815        0.894
##   499    262       1    0.851 0.02032        0.812        0.891
##   506    261       1    0.847 0.02050        0.808        0.888
##   510    260       1    0.844 0.02068        0.804        0.886
##   537    259       1    0.841 0.02086        0.801        0.883
##   563    258       2    0.834 0.02120        0.794        0.877
##   570    256       1    0.831 0.02137        0.790        0.874
##   576    255       1    0.828 0.02153        0.787        0.871
##   587    254       1    0.824 0.02169        0.783        0.868
##   591    253       1    0.821 0.02185        0.780        0.865
##   594    252       1    0.818 0.02200        0.776        0.862
##   595    251       1    0.815 0.02215        0.772        0.859
```

```
##   599    250         1    0.811 0.02230        0.769         0.856
##   612    249         1    0.808 0.02245        0.765         0.853
##   622    248         1    0.805 0.02260        0.762         0.850
##   659    247         1    0.802 0.02274        0.758         0.847
##   663    246         1    0.798 0.02288        0.755         0.845
##   665    245         1    0.795 0.02302        0.751         0.842
##   670    244         1    0.792 0.02315        0.748         0.839
##   673    243         1    0.789 0.02328        0.744         0.836
##   685    242         1    0.785 0.02341        0.741         0.833
##   687    241         1    0.782 0.02354        0.737         0.830
##   692    240         1    0.779 0.02367        0.734         0.827
##   709    239         1    0.776 0.02379        0.730         0.824
##   716    238         1    0.772 0.02392        0.727         0.821
##   717    237         1    0.769 0.02404        0.723         0.818
##   718    236         1    0.766 0.02415        0.720         0.815
##   721    235         1    0.763 0.02427        0.716         0.812
##   743    234         1    0.759 0.02438        0.713         0.809
##   753    233         1    0.756 0.02450        0.710         0.806
##   758    232         1    0.753 0.02461        0.706         0.803
##   760    231         1    0.750 0.02472        0.703         0.800
##   761    230         1    0.746 0.02482        0.699         0.797
##   770    229         1    0.743 0.02493        0.696         0.794
##   774    228         1    0.740 0.02503        0.692         0.790
##   775    227         1    0.736 0.02513        0.689         0.787
##   832    226         1    0.733 0.02523        0.685         0.784
##   833    225         1    0.730 0.02533        0.682         0.781
##   840    224         1    0.727 0.02542        0.679         0.778
##   845    223         1    0.723 0.02552        0.675         0.775
##   854    222         1    0.720 0.02561        0.672         0.772
##   863    221         1    0.717 0.02570        0.668         0.769
##   874    220         1    0.714 0.02579        0.665         0.766
##   883    219         1    0.710 0.02588        0.661         0.763
##   887    218         1    0.707 0.02596        0.658         0.760
##   901    217         1    0.704 0.02605        0.655         0.757
##   924    216         1    0.701 0.02613        0.651         0.754
##   928    215         1    0.697 0.02621        0.648         0.751
##   929    214         1    0.694 0.02629        0.644         0.748
##   936    213         1    0.691 0.02637        0.641         0.745
##   949    212         1    0.688 0.02644        0.638         0.741
##   957    211         1    0.684 0.02652        0.634         0.738
##   961    210         1    0.681 0.02659        0.631         0.735
##   963    209         1    0.678 0.02666        0.628         0.732
##   966    208         1    0.675 0.02673        0.624         0.729
##   976    207         1    0.671 0.02680        0.621         0.726
##  1021    206         1    0.668 0.02687        0.617         0.723
##  1031    205         1    0.665 0.02693        0.614         0.720
##  1048    204         1    0.662 0.02700        0.611         0.717
##  1070    203         1    0.658 0.02706        0.607         0.714
##  1079    202         1    0.655 0.02712        0.604         0.710
##  1083    201         1    0.652 0.02718        0.601         0.707
##  1101    200         1    0.649 0.02724        0.597         0.704
##  1133    199         1    0.645 0.02730        0.594         0.701
##  1134    198         1    0.642 0.02736        0.591         0.698
##  1136    197         1    0.639 0.02741        0.587         0.695
```

```
##  1139    196       1    0.635 0.02746        0.584        0.692
##  1159    195       1    0.632 0.02751        0.581        0.689
##  1166    194       1    0.629 0.02757        0.577        0.685
##  1178    193       1    0.626 0.02761        0.574        0.682
##  1195    192       1    0.622 0.02766        0.571        0.679
##  1198    191       1    0.619 0.02771        0.567        0.676
##  1209    190       1    0.616 0.02775        0.564        0.673
##  1216    189       1    0.613 0.02780        0.561        0.670
##  1230    188       1    0.609 0.02784        0.557        0.666
##  1237    187       1    0.606 0.02788        0.554        0.663
##  1246    186       1    0.603 0.02792        0.551        0.660
##  1262    185       1    0.600 0.02796        0.547        0.657
##  1272    184       1    0.596 0.02800        0.544        0.654
##  1290    183       1    0.593 0.02803        0.541        0.651
##  1295    182       1    0.590 0.02807        0.537        0.648
##  1304    181       1    0.587 0.02810        0.534        0.644
##  1313    180       1    0.583 0.02813        0.531        0.641
##  1314    179       1    0.580 0.02816        0.527        0.638
##  1327    178       1    0.577 0.02819        0.524        0.635
##  1363    177       1    0.574 0.02822        0.521        0.632
##  1375    176       1    0.570 0.02825        0.518        0.628
##  1434    175       1    0.567 0.02828        0.514        0.625
##  1437    174       1    0.564 0.02830        0.511        0.622
##  1447    173       1    0.561 0.02832        0.508        0.619
##  1482    172       1    0.557 0.02835        0.504        0.616
##  1530    171       1    0.554 0.02837        0.501        0.612
##  1548    170       1    0.551 0.02839        0.498        0.609
##  1656    169       1    0.547 0.02841        0.495        0.606
##  1679    168       1    0.544 0.02842        0.491        0.603
##  1692    167       1    0.541 0.02844        0.488        0.600
##  1723    166       1    0.538 0.02845        0.485        0.596
##  1745    165       1    0.534 0.02847        0.481        0.593
##  1772    164       1    0.531 0.02848        0.478        0.590
##  1788    163       1    0.528 0.02849        0.475        0.587
##  1790    162       1    0.525 0.02850        0.472        0.584
##  1818    159       1    0.521 0.02851        0.468        0.580
##  1875    152       1    0.518 0.02853        0.465        0.577
##  1896    150       1    0.514 0.02855        0.461        0.574
##  1907    147       1    0.511 0.02857        0.458        0.570
##  1915    146       1    0.507 0.02858        0.454        0.567
##  1950    143       1    0.504 0.02860        0.451        0.563
##  2077    133       1    0.500 0.02864        0.447        0.560
##  2083    132       1    0.496 0.02867        0.443        0.556
##  2085    131       1    0.493 0.02870        0.439        0.552
##  2133    119       1    0.488 0.02876        0.435        0.548
##  2171    107       1    0.484 0.02885        0.431        0.544
##  2213     93       1    0.479 0.02900        0.425        0.539
##  2257     82       1    0.473 0.02923        0.419        0.534
##  2284     76       1    0.467 0.02950        0.412        0.528
##  2287     75       1    0.460 0.02976        0.406        0.523
##  2351     66       1    0.453 0.03011        0.398        0.516
##  2527     47       1    0.444 0.03098        0.387        0.509
##  2552     42       1    0.433 0.03199        0.375        0.501
##  2789     16       1    0.406 0.03983        0.335        0.492
```

```
##
##                 rx=2
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    24    300       1    0.997 0.00333        0.990        1.000
##    56    299       1    0.993 0.00470        0.984        1.000
##    93    298       1    0.990 0.00574        0.979        1.000
##   122    297       1    0.987 0.00662        0.974        1.000
##   129    296       1    0.983 0.00739        0.969        0.998
##   133    295       1    0.980 0.00808        0.964        0.996
##   150    294       1    0.977 0.00872        0.960        0.994
##   165    293       1    0.973 0.00930        0.955        0.992
##   171    292       2    0.967 0.01036        0.947        0.987
##   191    290       1    0.963 0.01085        0.942        0.985
##   206    289       1    0.960 0.01131        0.938        0.982
##   219    288       2    0.953 0.01218        0.930        0.978
##   222    286       1    0.950 0.01258        0.926        0.975
##   226    285       1    0.947 0.01297        0.922        0.972
##   232    284       1    0.943 0.01335        0.918        0.970
##   257    283       1    0.940 0.01371        0.914        0.967
##   283    282       1    0.937 0.01406        0.910        0.965
##   314    281       2    0.930 0.01473        0.902        0.959
##   316    279       1    0.927 0.01505        0.898        0.957
##   323    278       1    0.923 0.01536        0.894        0.954
##   342    277       1    0.920 0.01566        0.890        0.951
##   343    276       1    0.917 0.01596        0.886        0.948
##   349    275       1    0.913 0.01624        0.882        0.946
##   355    274       1    0.910 0.01652        0.878        0.943
##   356    273       1    0.907 0.01680        0.874        0.940
##   362    272       1    0.903 0.01706        0.871        0.937
##   366    271       1    0.900 0.01732        0.867        0.935
##   376    270       1    0.897 0.01757        0.863        0.932
##   382    269       1    0.893 0.01782        0.859        0.929
##   402    268       1    0.890 0.01806        0.855        0.926
##   406    267       1    0.887 0.01830        0.852        0.923
##   420    266       1    0.883 0.01853        0.848        0.920
##   422    265       1    0.880 0.01876        0.844        0.918
##   430    264       1    0.877 0.01898        0.840        0.915
##   438    263       1    0.873 0.01920        0.836        0.912
##   439    262       1    0.870 0.01942        0.833        0.909
##   443    261       1    0.867 0.01963        0.829        0.906
##   444    260       1    0.863 0.01983        0.825        0.903
##   472    259       1    0.860 0.02003        0.822        0.900
##   475    258       1    0.857 0.02023        0.818        0.897
##   486    257       1    0.853 0.02043        0.814        0.894
##   499    256       1    0.850 0.02062        0.811        0.891
##   512    255       1    0.847 0.02080        0.807        0.888
##   522    254       1    0.843 0.02099        0.803        0.885
##   546    253       1    0.840 0.02117        0.800        0.883
##   553    252       1    0.837 0.02134        0.796        0.880
##   559    251       1    0.833 0.02152        0.792        0.877
##   569    250       1    0.830 0.02169        0.789        0.874
##   573    249       1    0.827 0.02185        0.785        0.871
##   580    248       1    0.823 0.02202        0.781        0.868
##   582    247       1    0.820 0.02218        0.778        0.865
```

```
##   589   246       1   0.817 0.02234       0.774       0.862
##   602   245       1   0.813 0.02250       0.770       0.859
##   608   244       1   0.810 0.02265       0.767       0.856
##   628   243       1   0.807 0.02280       0.763       0.853
##   629   242       1   0.803 0.02295       0.760       0.850
##   642   241       1   0.800 0.02309       0.756       0.847
##   643   240       1   0.797 0.02324       0.752       0.844
##   647   239       1   0.793 0.02338       0.749       0.841
##   664   238       1   0.790 0.02352       0.745       0.837
##   669   237       1   0.787 0.02365       0.742       0.834
##   675   236       1   0.783 0.02379       0.738       0.831
##   678   235       1   0.780 0.02392       0.735       0.828
##   684   234       1   0.777 0.02405       0.731       0.825
##   706   233       1   0.773 0.02417       0.727       0.822
##   708   232       1   0.770 0.02430       0.724       0.819
##   709   231       1   0.767 0.02442       0.720       0.816
##   720   230       1   0.763 0.02454       0.717       0.813
##   723   229       1   0.760 0.02466       0.713       0.810
##   729   228       1   0.757 0.02477       0.710       0.807
##   730   227       1   0.753 0.02489       0.706       0.804
##   739   226       1   0.750 0.02500       0.703       0.801
##   743   225       1   0.747 0.02511       0.699       0.798
##   755   224       1   0.743 0.02522       0.696       0.794
##   759   223       2   0.737 0.02543       0.688       0.788
##   764   221       1   0.733 0.02553       0.685       0.785
##   766   220       1   0.730 0.02563       0.681       0.782
##   797   219       1   0.727 0.02573       0.678       0.779
##   806   218       1   0.723 0.02583       0.674       0.776
##   833   217       1   0.720 0.02592       0.671       0.773
##   846   216       1   0.717 0.02602       0.667       0.770
##   858   215       1   0.713 0.02611       0.664       0.766
##   875   214       1   0.710 0.02620       0.660       0.763
##   885   213       1   0.707 0.02629       0.657       0.760
##   890   212       1   0.703 0.02637       0.653       0.757
##   902   211       1   0.700 0.02646       0.650       0.754
##   905   210       1   0.697 0.02654       0.647       0.751
##   909   209       1   0.693 0.02662       0.643       0.748
##   938   208       1   0.690 0.02670       0.640       0.744
##   939   207       1   0.687 0.02678       0.636       0.741
##   940   206       1   0.683 0.02686       0.633       0.738
##   942   205       1   0.680 0.02693       0.629       0.735
##   944   204       1   0.677 0.02701       0.626       0.732
##   952   203       1   0.673 0.02708       0.622       0.729
##   961   202       2   0.667 0.02722       0.615       0.722
##   968   200       1   0.663 0.02728       0.612       0.719
##   969   199       1   0.660 0.02735       0.609       0.716
##   986   198       1   0.657 0.02741       0.605       0.713
##   997   197       1   0.653 0.02748       0.602       0.709
##  1018   196       1   0.650 0.02754       0.598       0.706
##  1034   195       1   0.647 0.02760       0.595       0.703
##  1037   194       1   0.643 0.02766       0.591       0.700
##  1041   193       1   0.640 0.02771       0.588       0.697
##  1046   192       1   0.637 0.02777       0.585       0.693
##  1055   191       1   0.633 0.02782       0.581       0.690
```

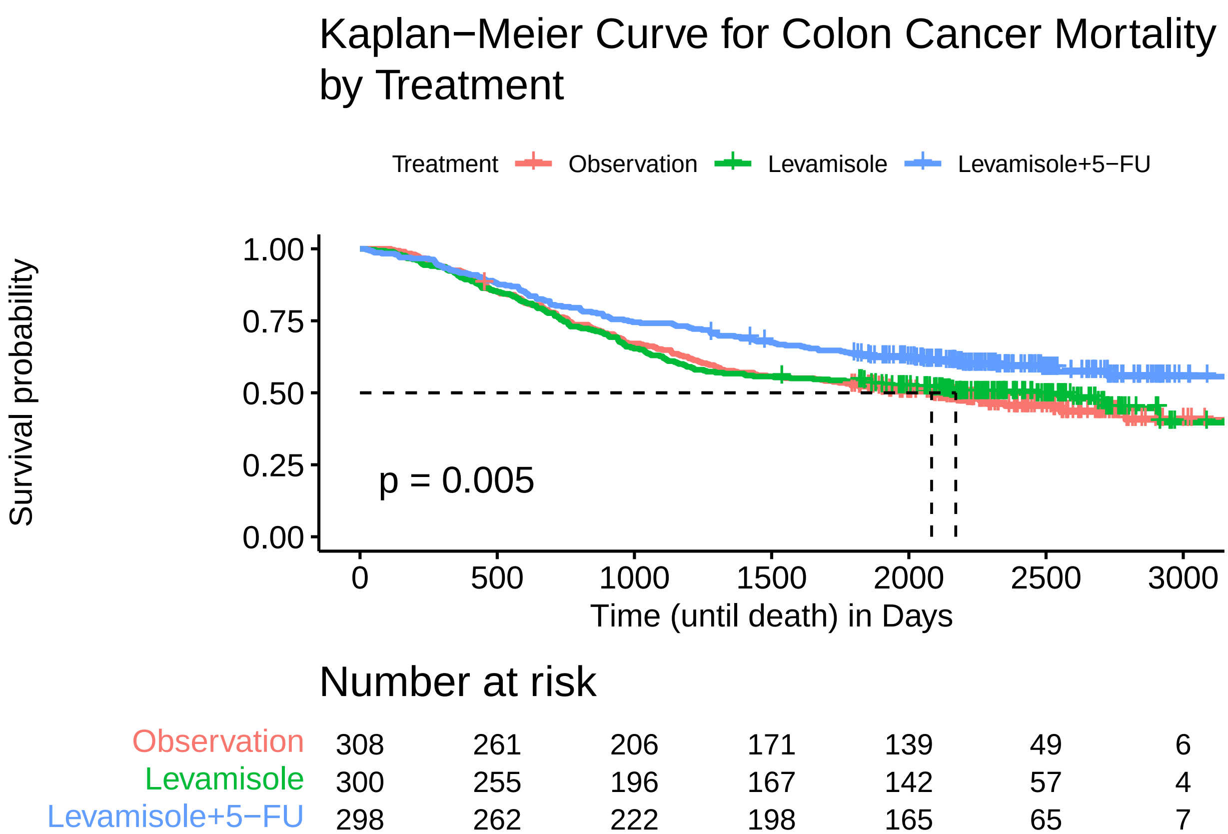
```
##  1061    190       1    0.630 0.02787        0.578        0.687
##  1092    189       1    0.627 0.02793        0.574        0.684
##  1103    188       1    0.623 0.02798        0.571        0.681
##  1105    187       1    0.620 0.02802        0.567        0.677
##  1112    186       1    0.617 0.02807        0.564        0.674
##  1117    185       1    0.613 0.02812        0.561        0.671
##  1122    184       1    0.610 0.02816        0.557        0.668
##  1145    183       1    0.607 0.02820        0.554        0.665
##  1154    182       1    0.603 0.02824        0.550        0.661
##  1161    181       1    0.600 0.02828        0.547        0.658
##  1178    180       1    0.597 0.02832        0.544        0.655
##  1186    179       1    0.593 0.02836        0.540        0.652
##  1191    178       1    0.590 0.02840        0.537        0.648
##  1207    177       1    0.587 0.02843        0.534        0.645
##  1215    176       1    0.583 0.02846        0.530        0.642
##  1219    175       1    0.580 0.02850        0.527        0.639
##  1252    174       1    0.577 0.02853        0.523        0.635
##  1262    173       1    0.573 0.02856        0.520        0.632
##  1295    172       1    0.570 0.02858        0.517        0.629
##  1325    171       1    0.567 0.02861        0.513        0.626
##  1399    170       1    0.563 0.02863        0.510        0.622
##  1405    169       1    0.560 0.02866        0.507        0.619
##  1434    168       1    0.557 0.02868        0.503        0.616
##  1509    167       1    0.553 0.02870        0.500        0.613
##  1568    165       1    0.550 0.02872        0.496        0.609
##  1652    164       1    0.547 0.02874        0.493        0.606
##  1709    163       1    0.543 0.02876        0.490        0.603
##  1768    162       1    0.540 0.02878        0.486        0.599
##  1829    159       1    0.537 0.02880        0.483        0.596
##  1839    157       1    0.533 0.02882        0.480        0.593
##  1850    156       1    0.530 0.02883        0.476        0.589
##  1851    155       1    0.526 0.02885        0.473        0.586
##  1885    152       1    0.523 0.02887        0.469        0.583
##  1932    149       1    0.519 0.02889        0.466        0.579
##  2023    141       1    0.516 0.02892        0.462        0.576
##  2079    135       1    0.512 0.02895        0.458        0.572
##  2128    128       1    0.508 0.02900        0.454        0.568
##  2152    119       1    0.504 0.02907        0.450        0.564
##  2171    115       1    0.499 0.02914        0.445        0.560
##  2458     64       1    0.491 0.02971        0.436        0.553
##  2593     41       1    0.479 0.03131        0.422        0.545
##  2683     32       1    0.464 0.03373        0.403        0.535
##  2718     25       1    0.446 0.03714        0.379        0.525
##  2910      9       1    0.396 0.05719        0.299        0.526
## 
##                 rx=3 
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    23    298       1    0.997 0.00335        0.990        1.000
##    34    297       1    0.993 0.00473        0.984        1.000
##    45    296       1    0.990 0.00578        0.979        1.000
##    52    295       1    0.987 0.00667        0.974        1.000
##    79    294       1    0.983 0.00744        0.969        0.998
##   127    293       1    0.980 0.00814        0.964        0.996
##   138    292       1    0.977 0.00877        0.959        0.994
```

```
##   141    291       1    0.973 0.00936        0.955        0.992
##   144    290       1    0.970 0.00991        0.951        0.989
##   186    289       1    0.966 0.01043        0.946        0.987
##   251    288       1    0.963 0.01092        0.942        0.985
##   269    287       1    0.960 0.01139        0.938        0.982
##   271    286       1    0.956 0.01183        0.933        0.980
##   274    285       1    0.953 0.01226        0.929        0.977
##   276    284       1    0.950 0.01267        0.925        0.975
##   279    283       1    0.946 0.01306        0.921        0.972
##   283    282       1    0.943 0.01344        0.917        0.970
##   293    281       1    0.940 0.01380        0.913        0.967
##   302    280       1    0.936 0.01415        0.909        0.964
##   304    279       1    0.933 0.01449        0.905        0.962
##   324    278       1    0.930 0.01483        0.901        0.959
##   326    277       1    0.926 0.01515        0.897        0.956
##   340    276       1    0.923 0.01546        0.893        0.954
##   355    275       1    0.919 0.01576        0.889        0.951
##   363    274       1    0.916 0.01606        0.885        0.948
##   389    273       1    0.913 0.01635        0.881        0.945
##   400    272       1    0.909 0.01663        0.877        0.943
##   428    271       1    0.906 0.01690        0.874        0.940
##   430    270       1    0.903 0.01717        0.870        0.937
##   441    269       1    0.899 0.01743        0.866        0.934
##   448    268       1    0.896 0.01769        0.862        0.931
##   454    267       1    0.893 0.01793        0.858        0.928
##   460    266       1    0.889 0.01818        0.854        0.926
##   484    265       1    0.886 0.01842        0.851        0.923
##   490    264       1    0.883 0.01865        0.847        0.920
##   498    263       1    0.879 0.01888        0.843        0.917
##   503    262       1    0.876 0.01910        0.839        0.914
##   529    261       1    0.872 0.01932        0.835        0.911
##   550    260       1    0.869 0.01954        0.832        0.908
##   576    259       1    0.866 0.01975        0.828        0.905
##   578    258       1    0.862 0.01995        0.824        0.902
##   580    257       1    0.859 0.02016        0.820        0.899
##   583    256       1    0.856 0.02036        0.817        0.897
##   592    255       1    0.852 0.02055        0.813        0.894
##   601    254       1    0.849 0.02074        0.809        0.891
##   603    253       1    0.846 0.02093        0.806        0.888
##   609    252       1    0.842 0.02111        0.802        0.885
##   614    251       1    0.839 0.02129        0.798        0.882
##   616    250       1    0.836 0.02147        0.795        0.879
##   641    249       1    0.832 0.02165        0.791        0.876
##   642    248       1    0.829 0.02182        0.787        0.873
##   643    247       1    0.826 0.02199        0.784        0.870
##   666    246       1    0.822 0.02215        0.780        0.867
##   674    245       1    0.819 0.02231        0.776        0.864
##   692    244       2    0.812 0.02263        0.769        0.858
##   693    242       1    0.809 0.02278        0.765        0.855
##   696    241       1    0.805 0.02293        0.762        0.852
##   712    240       1    0.802 0.02308        0.758        0.849
##   736    239       1    0.799 0.02323        0.754        0.846
##   765    238       1    0.795 0.02337        0.751        0.842
##   802    237       2    0.789 0.02365        0.744        0.836
```

```
##   806    235       1    0.785 0.02379        0.740        0.833
##   811    234       1    0.782 0.02392        0.736        0.830
##   844    233       1    0.779 0.02405        0.733        0.827
##   862    232       1    0.775 0.02418        0.729        0.824
##   884    231       1    0.772 0.02431        0.726        0.821
##   887    230       2    0.765 0.02456        0.718        0.815
##   905    228       1    0.762 0.02468        0.715        0.812
##   911    227       1    0.758 0.02480        0.711        0.809
##   916    226       1    0.755 0.02491        0.708        0.805
##   961    225       1    0.752 0.02503        0.704        0.802
##   977    224       1    0.748 0.02514        0.701        0.799
##   993    223       1    0.745 0.02525        0.697        0.796
##  1022    222       1    0.742 0.02536        0.694        0.793
##  1138    221       1    0.738 0.02546        0.690        0.790
##  1145    220       1    0.735 0.02557        0.686        0.787
##  1151    219       1    0.732 0.02567        0.683        0.784
##  1193    218       1    0.728 0.02577        0.679        0.780
##  1201    217       1    0.725 0.02587        0.676        0.777
##  1212    216       1    0.721 0.02597        0.672        0.774
##  1246    215       1    0.718 0.02606        0.669        0.771
##  1273    214       1    0.715 0.02616        0.665        0.768
##  1276    213       2    0.708 0.02634        0.658        0.762
##  1279    211       1    0.705 0.02643        0.655        0.758
##  1302    209       1    0.701 0.02651        0.651        0.755
##  1306    208       1    0.698 0.02660        0.648        0.752
##  1365    207       1    0.695 0.02668        0.644        0.749
##  1387    206       1    0.691 0.02677        0.641        0.746
##  1388    205       1    0.688 0.02685        0.637        0.743
##  1424    203       1    0.684 0.02693        0.634        0.739
##  1439    202       1    0.681 0.02701        0.630        0.736
##  1446    201       1    0.678 0.02708        0.627        0.733
##  1495    199       1    0.674 0.02716        0.623        0.730
##  1511    198       1    0.671 0.02724        0.620        0.726
##  1521    197       1    0.667 0.02731        0.616        0.723
##  1550    196       1    0.664 0.02738        0.612        0.720
##  1607    195       1    0.661 0.02745        0.609        0.717
##  1620    194       1    0.657 0.02752        0.605        0.713
##  1637    193       1    0.654 0.02759        0.602        0.710
##  1668    192       1    0.650 0.02766        0.598        0.707
##  1671    191       1    0.647 0.02772        0.595        0.704
##  1752    190       1    0.644 0.02778        0.591        0.700
##  1767    189       1    0.640 0.02784        0.588        0.697
##  1783    188       1    0.637 0.02790        0.584        0.694
##  1798    187       1    0.633 0.02796        0.581        0.691
##  1812    185       1    0.630 0.02802        0.577        0.687
##  1831    180       1    0.626 0.02808        0.574        0.684
##  1856    178       1    0.623 0.02814        0.570        0.681
##  1995    167       1    0.619 0.02822        0.566        0.677
##  2021    162       1    0.615 0.02830        0.562        0.673
##  2052    156       1    0.611 0.02840        0.558        0.670
##  2127    143       1    0.607 0.02852        0.554        0.666
##  2174    133       1    0.603 0.02867        0.549        0.662
##  2197    124       1    0.598 0.02884        0.544        0.657
##  2318    100       1    0.592 0.02917        0.537        0.652
```

```
## 2482     72       1    0.584 0.02990        0.528        0.645
## 2542     53       1    0.573 0.03130        0.514        0.637
## 2725     35       1    0.556 0.03441        0.493        0.628
```

```r
ggsurvplot(death.fit, conf.int = F, break.time.by = 500, pval = TRUE,
           font.x.size = 12, font.y.size = 12, font.legend.size = 9, surv.median.line = "hv",
           legend.title = "Treatment", legend.labs = c("Observation", "Levamisole","Levamisole+5-FU"),
           title = "Kaplan-Meier Curve for Colon Cancer Mortality \nby Treatment",
           xlab = "Time (until death) in Days",
           risk.table = T, risk.table.height = 0.25, risk.table.fontsize = 4,
           tables.theme = theme_cleantable())
```



From the plot above, there is some indication that patients who received the adjuvant treatment with levamisole plus fluorouracil (Lev+5FU) have a higher survival probability than patients with no further treatment and patients who received the treatment with levamisole alone. The median survival time for observation group and levamisole group are approximately 2100 days and 2200 days. However, until the end of the trial, the survival probability of Levamisole+5-FU treatment group is greater than 50% as we fail to observe the curve doesn't cross 50%, which means the median survival is simply undefined.

3. Log-Rank Test

Noticing the difference of survival probability between the three treatment groups, we do a Log-rank hypothesis test to test the null hypothesis of no difference among the three treatments in the mortality model.

```r
survdiff(Surv(time, status) ~ rx, data = colon.death)
```

```
## Call:
## survdiff(formula = Surv(time, status) ~ rx, data = colon.death)
##
##        N Observed Expected (O-E)^2/E (O-E)^2/V
## rx=1 308      165      145      2.67      3.99
## rx=2 300      154      141      1.13      1.66
## rx=3 298      122      154      6.77     10.44
##
##  Chisq= 10.6  on 2 degrees of freedom, p= 0.005
```

From this log-rank test, we get a p-value that is closed to 0.005, which is significant at a 0.05 level. We want to conclude that there is a significant difference among the three treatments in the mortality model.

4. Cox PH Model

4.1 Model Selection

We now use automatic stepwise selection with Akaike information criterion (AIC) to determine the covariates that best represent an appropriate cox proportional hazards model for the event of death.

```r
# fit all the variables in the model
d.model.full <- coxph(Surv(time, status) ~ . -etype, data = colon.death)

# stepwise selection with AIC criterion
d.model.aic <- step(d.model.full, direction = "both", k = 2)
```

```
## Start:  AIC=5583.24
## Surv(time, status) ~ (rx + sex + age + obstruct + perfor + adhere +
##     differ + extent + surg + node4 + etype) - etype
##
##            Df    AIC
## - perfor    1 5581.2
## - sex       1 5581.3
## - adhere    1 5582.6
## <none>        5583.2
## - age       1 5584.9
## - surg      1 5586.3
## - obstruct  1 5586.8
## - differ    2 5587.5
## - rx        2 5590.7
## - extent    3 5591.9
## - node4     1 5662.1
##
## Step:  AIC=5581.24
## Surv(time, status) ~ rx + sex + age + obstruct + adhere + differ +
##     extent + surg + node4
##
```

```
##            Df    AIC
## - sex       1 5579.4
## - adhere    1 5580.6
## <none>        5581.2
## - age       1 5582.9
## + perfor    1 5583.2
## - surg      1 5584.3
## - obstruct  1 5584.9
## - differ    2 5585.5
## - rx        2 5588.7
## - extent    3 5590.0
## - node4     1 5660.2
##
## Step:  AIC=5579.35
## Surv(time, status) ~ rx + age + obstruct + adhere + differ +
##     extent + surg + node4
##
##            Df    AIC
## - adhere    1 5578.7
## <none>        5579.4
## - age       1 5581.0
## + sex       1 5581.2
## + perfor    1 5581.3
## - surg      1 5582.5
## - obstruct  1 5582.9
## - differ    2 5583.6
## - rx        2 5586.9
## - extent    3 5588.0
## - node4     1 5658.2
##
## Step:  AIC=5578.74
## Surv(time, status) ~ rx + age + obstruct + differ + extent +
##     surg + node4
##
##            Df    AIC
## <none>        5578.7
## + adhere    1 5579.4
## + sex       1 5580.6
## + perfor    1 5580.7
## - age       1 5580.7
## - surg      1 5582.1
## - obstruct  1 5582.3
## - differ    2 5583.7
## - rx        2 5586.4
## - extent    3 5588.4
## - node4     1 5657.3
```

The resulting model with the lowest AIC is: Surv(time, status) ~ obstruct + differ + extent + surg + node4 + age + rx

Next, we used the Analysis of Deviance procedure to get the proper Likelihood Ratio Test to confirm if each of the covariates selected by the stepwise selection method is significant to include in the Cox Proportional Model.

```r
anova(d.model.aic)
```

```
## Analysis of Deviance Table
##  Cox model: response is Surv(time, status)
## Terms added sequentially (first to last)
##
##           loglik   Chisq Df Pr(>|Chi|)
## NULL     -2847.5
## rx       -2842.0 10.9755  2  0.0041372 **
## age      -2841.8  0.5855  1  0.4441715
## obstruct -2839.4  4.7384  1  0.0294972 *
## differ   -2831.3 16.1461  2  0.0003118 ***
## extent   -2820.6 21.4045  3  8.675e-05 ***
## surg     -2818.6  3.9238  1  0.0476071 *
## node4    -2778.4 80.5441  1  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can see that p-values for covariates "obstruct, differ, extent, surg, node4 and rx" are much smaller than 0.05, except for "age", indicating that they have a significant effect on time until death. Therefore, we will include these 6 covariates in our Cox PH model.

Therefore, we obtain the resulting model, which is Surv(time, status) ~ obstruct + differ + extent + surg + node4 + rx.

4.2 Model Diagnostics

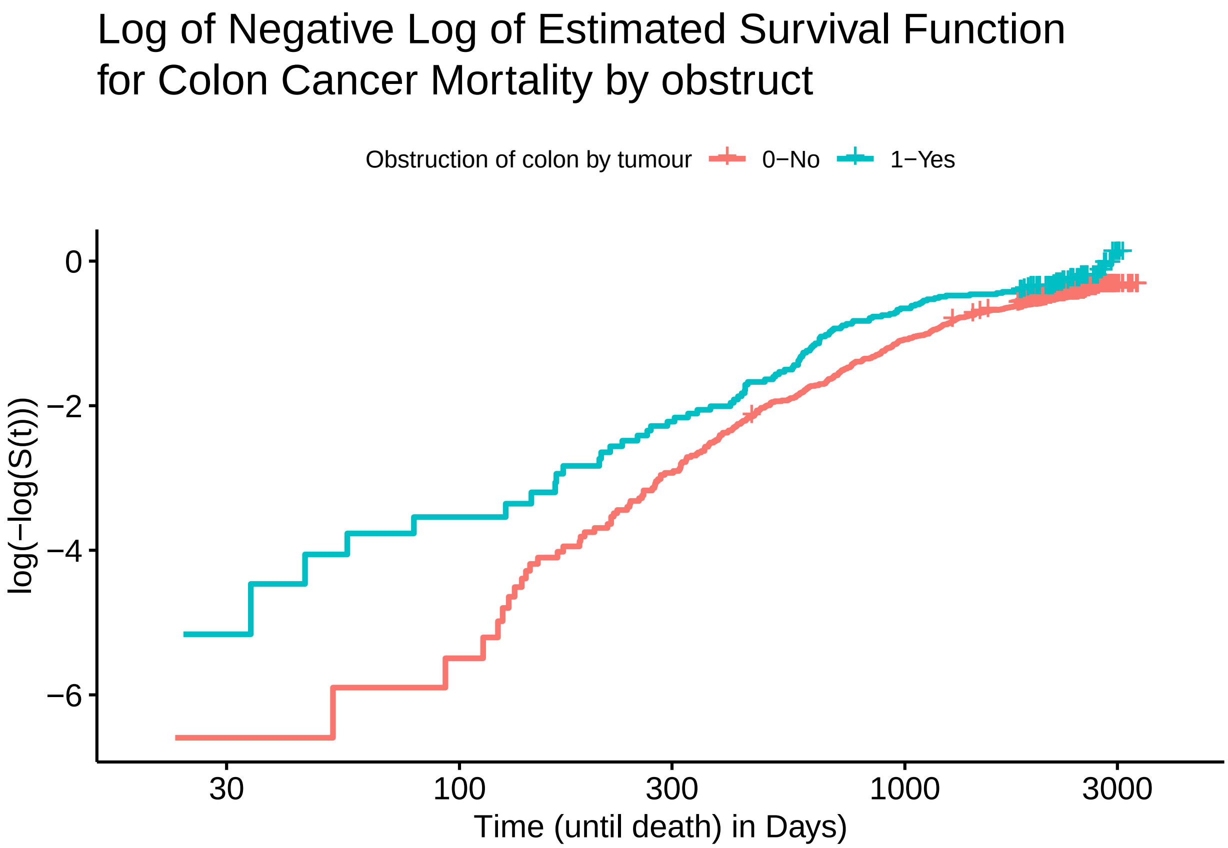
4.2.1 Check proportionality of hazard ratios

Log of Negative Log of Estimated Survival Function

To check the proportional hazards assumption for this model, we make diagnostic plots using log of negative log of estimated survival function. First comes to covariate obstruct.

```r
d.obstruct.fit <- survfit(Surv(time, status) ~ obstruct, data = colon.death)
cloglog_obstruct <- ggsurvplot(d.obstruct.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.l
                               fun = "cloglog",
                               xlim = c(20, 4000),
                               xlab = "Time (until death) in Days)",
                               title = "Log of Negative Log of Estimated Survival Function \nfor Colon C
                               legend.title = "Obstruction of colon by tumour",
                               legend.labs = c("0-No", "1-Yes"))

cloglog_obstruct
```

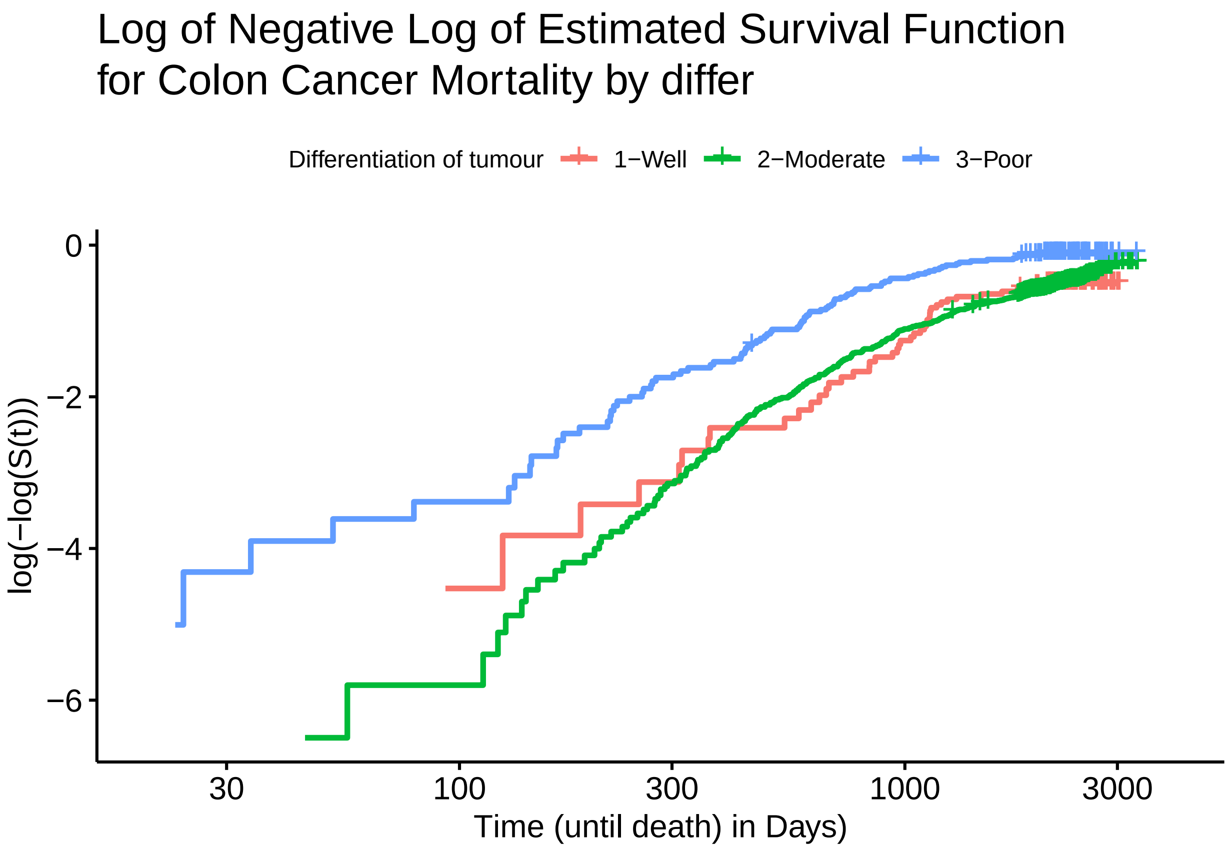


According to the plot, the distance between two obstruct curves begin to narrow after 2000 days which causes some concern that the assumption might be violated. However, it is also reasonable to assume that the curves are wider apparent earlier in the study since there are less occurrences of death before 2000 days. Hence we believe it is best to ignore the noisiness of the plot since the curves are roughly parallel after 2000 days. Thus, the cox proportional hazards assumption is valid to use for "obstruct".

We continue to plot the C-log-log plot for the covariate differ.

```
d.differ.fit <- survfit(Surv(time, status) ~ differ, data = colon.death)
cloglog_differ <- ggsurvplot(d.differ.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.legend
                             fun = "cloglog",
                             xlim = c(20, 4000),
                             xlab = "Time (until death) in Days)",
                             title = "Log of Negative Log of Estimated Survival Function \nfor Colon Ca
                             legend.title = "Differentiation of tumour",
                             legend.labs = c("1-Well", "2-Moderate","3-Poor"))

cloglog_differ
```

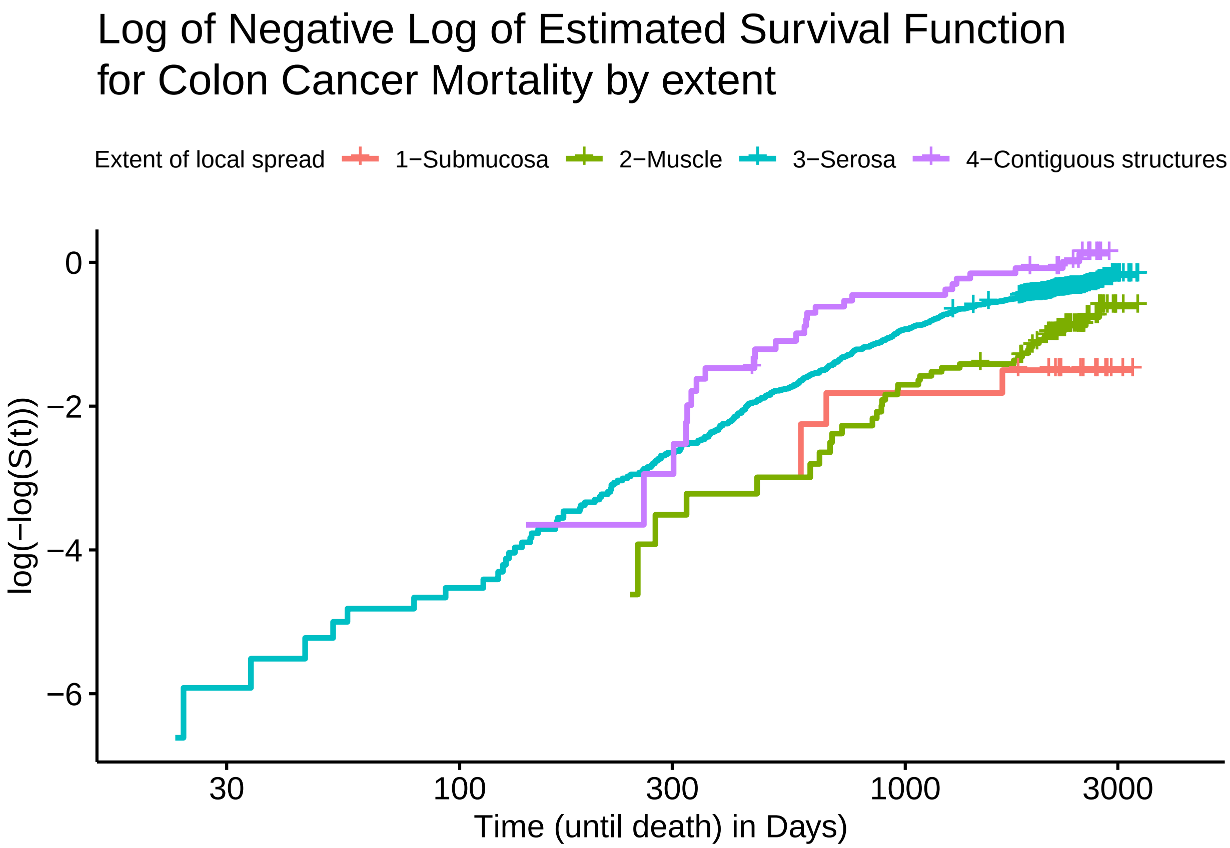


According to the plot, the curves in the C-log-log plot are crossing over after 300 days. The assumption of proportional hazard ratio between the three differ groups is violated as we fail to see three parallel lines against log time.

We continue to plot the C-log-log plot for the covariate extent.

```
d.extent.fit <- survfit(Surv(time, status) ~ extent, data = colon.death)
cloglog_extent <- ggsurvplot(d.extent.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.legend
                             fun = "cloglog",
                             xlim = c(20, 4000),
                             xlab = "Time (until death) in Days)",
                             title = "Log of Negative Log of Estimated Survival Function \nfor Colon Ca
                             legend.title = "Extent of local spread",
                             legend.labs = c("1-Submucosa", "2-Muscle", "3-Serosa", "4-Contiguous struc

cloglog_extent
```

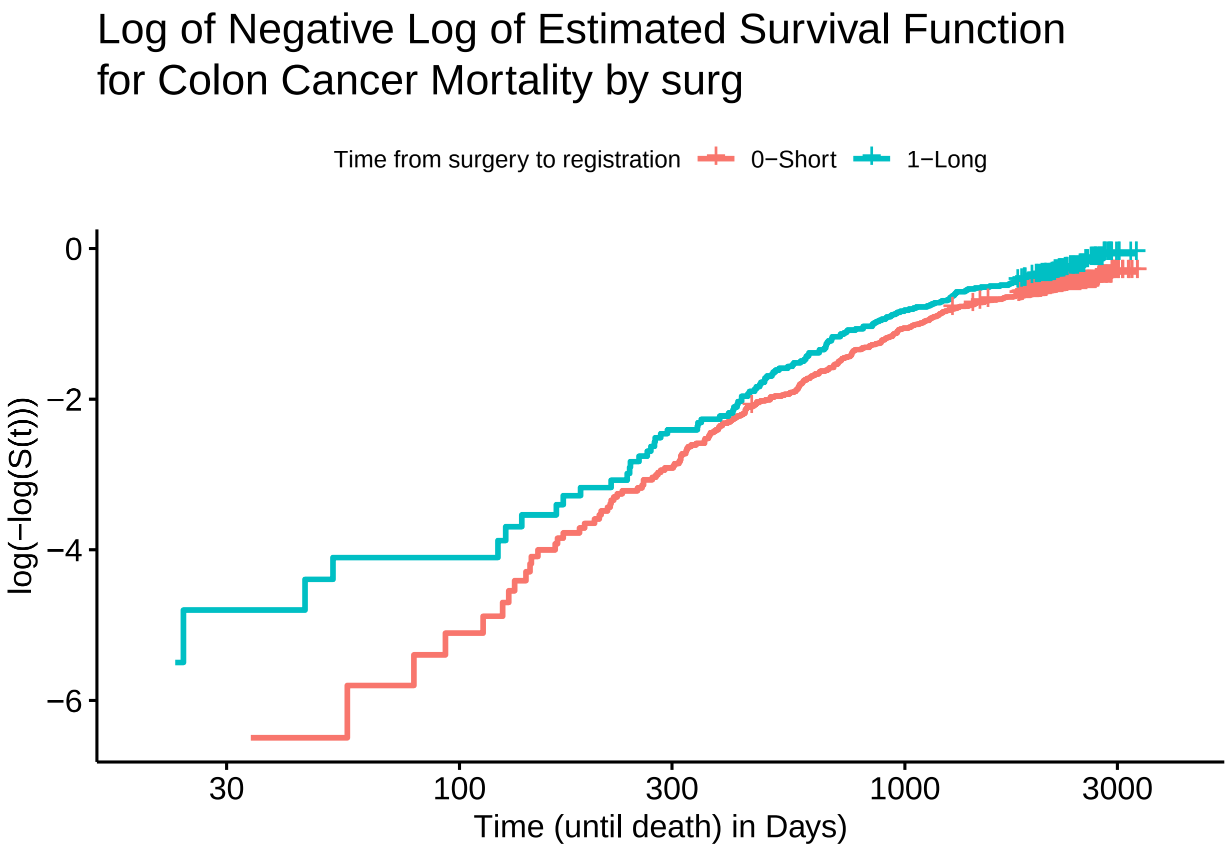


According to the plot, the curves in the C-log-log plot are crossing over after 100 days. The assumption of proportional hazard ratio of extent is violated as we fail to see four parallel lines against log time.

We continue to plot the C-log-log plot for the covariate surg.

```
d.surg.fit <- survfit(Surv(time, status) ~ surg, data = colon.death)
cloglog_surg <- ggsurvplot(d.surg.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.legend.si
                           fun = "cloglog",
                           xlim = c(20, 4000),
                           xlab = "Time (until death) in Days)",
                           title = "Log of Negative Log of Estimated Survival Function \nfor Colon Canc
                           legend.title = "Time from surgery to registration",
                           legend.labs = c("0-Short", "1-Long"))

cloglog_surg
```

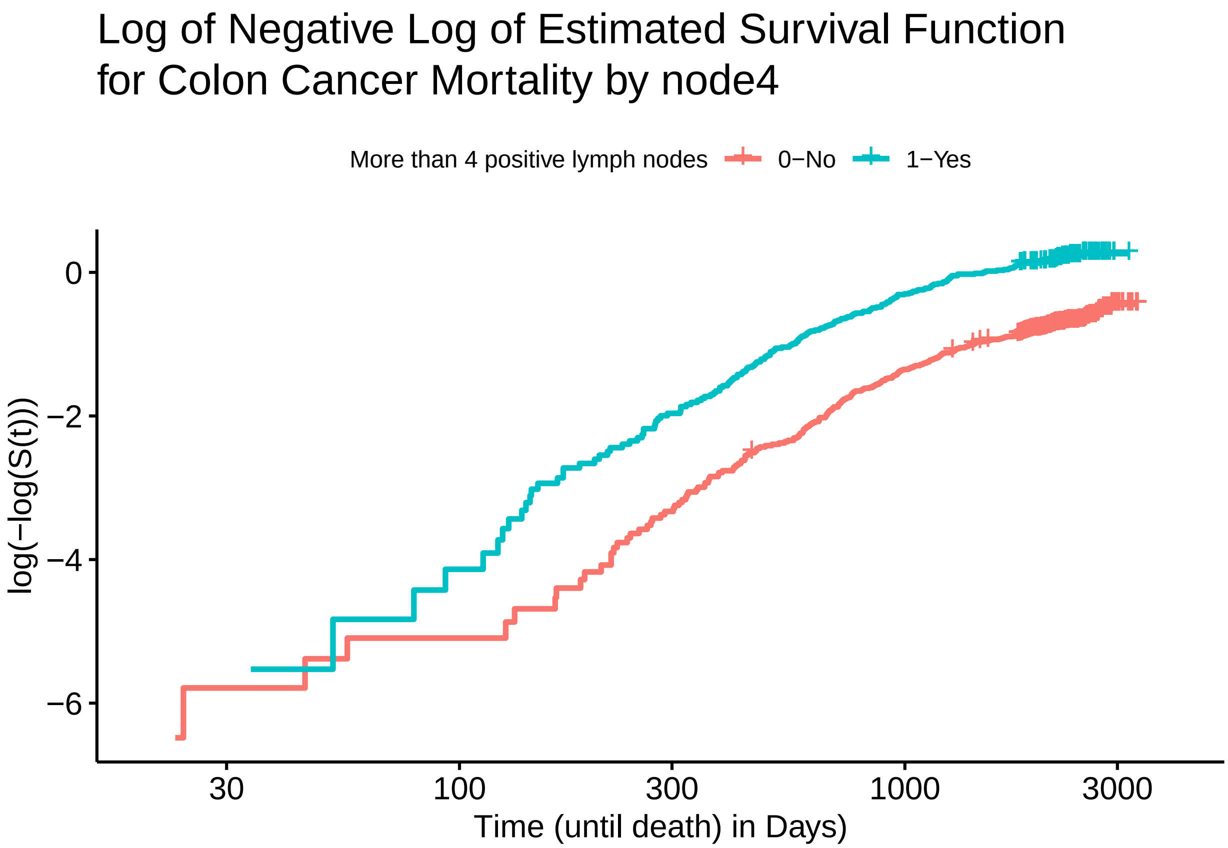


According to the plot, the distance between two surg curves begin to narrow after 100 days and becomes parallel to each other. We can assume that the cox proportional hazards assumption is valid to use for `surg`.

We continue to plot the C-log-log plot for the covariate node4.

```
d.node4.fit <- survfit(Surv(time, status) ~ node4, data = colon.death)
cloglog_node4 <- ggsurvplot(d.node4.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.legend.s
                            fun = "cloglog",
                            xlim = c(20, 4000),
                            xlab = "Time (until death) in Days)",
                            title = "Log of Negative Log of Estimated Survival Function \nfor Colon Canc
                            legend.title = "More than 4 positive lymph nodes",
                            legend.labs = c("0-No", "1-Yes"))

cloglog_node4
```

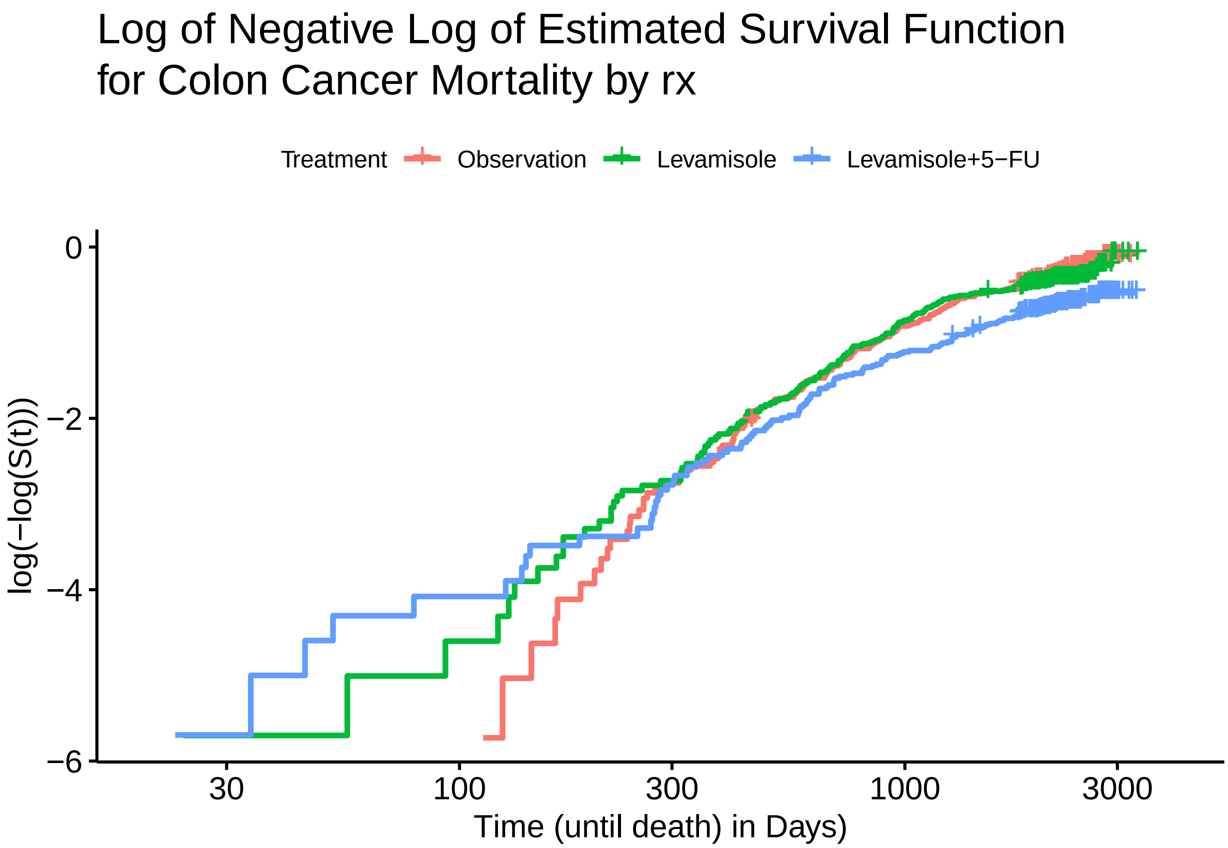


According to the plot, the two curves in this C-log-log plot cross over at the beginning of the study but appear to be parallel to each other after 100 days. Since the data is oftentimes noisy at the beginning of the study, the cross over does not cause too much concern. Overall, we believe that the cox proportional assumption is appropriate for the covariate node4 since the curves are consistently parallel throughout most of the study.

We continue to plot the C-log-log plot for the covariate rx.

```
d.surg.fit <- survfit(Surv(time, status) ~ rx, data = colon.death)
cloglog_rx <- ggsurvplot(d.surg.fit, conf.int = F, font.x.size = 12, font.y.size = 12, font.legend.size
                         fun = "cloglog",
                         xlim = c(20, 4000),
                         xlab = "Time (until death) in Days)",
                         title = "Log of Negative Log of Estimated Survival Function \nfor Colon Cancer
                         legend.title = "Treatment",
                         legend.labs = c("Observation", "Levamisole","Levamisole+5-FU"))

cloglog_rx
```



According to the plot, the distance between three treatment curves begin to narrow after 2000 days which causes some concern that the assumption might be violated. However, it is also reasonable to assume that the curves are wider apparent earlier in the study since there are less occurrences of death before 2000 days. Hence we believe it is best to ignore the noisiness of the plot since the curves are roughly parallel after 2000 days. Thus, the cox proportional hazards assumption is valid to use for this covariate.

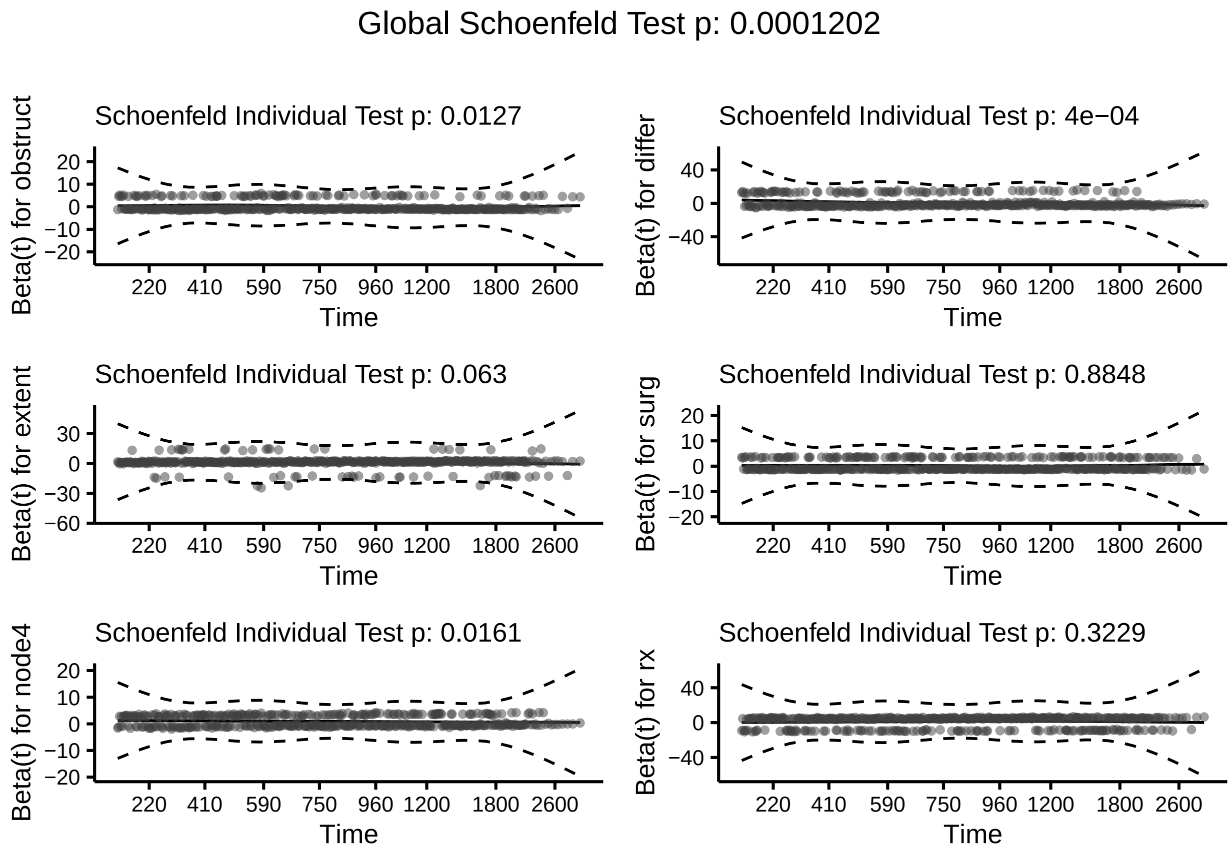
```
# combine all the cloglog plots and save them to a pdf file
splots <- list()
splots[[1]] <- cloglog_obstruct
splots[[2]] <- cloglog_differ
splots[[3]] <- cloglog_extent
splots[[4]] <- cloglog_surg
splots[[5]] <- cloglog_node4
splots[[6]] <- cloglog_rx
cloglog_plot = arrange_ggsurvplots(splots, print = FALSE, ncol = 2, nrow = 3)

ggsave(cloglog_plot,file = "./plot/d.C-log-log-plots.pdf",width = 12,height = 15)
ggsave(cloglog_plot,file = "./plot/d.C-log-log-plots.png",width = 12,height = 15)
```

Schoenfeld residuals

```
czph <- cox.zph(coxph(Surv(time, status) ~ obstruct + differ + extent + surg + node4 + rx, data = colon
schoenfeld_plot <- ggcoxzph(czph, font.main = 10, font.x = 10, font.y = 10, font.tickslab = 8,
                            point.alpha = 0.5, point.col = "grey25")

schoenfeld_plot
```




```
ggsave("./plot/d.schoenfeld residual_plots.pdf", arrangeGrob(grobs = schoenfeld_plot))
ggsave("./plot/d.schoenfeld residual_plots.png", arrangeGrob(grobs = schoenfeld_plot))
```

From the output above, the tests for covariates "obstruct", "node4", "differ" are statistically significant, and the global test is also statistically significant. Therefore, we can assume the violation of proportional hazards on these covariates, which requires corrections of non-proportional hazard ratio.

4.2.2 Test influential observations

```
# check outliers in term of dfbeta
outlier_dfbeta <- ggcoxdiagnostics(coxph(Surv(time, status) ~ obstruct + differ + extent + surg + node4
                                   type = "dfbeta", linear.predictions = FALSE, ggtheme = theme_bw())

ggsave(outlier_dfbeta, file = "./plot/d.outlier_dfbeta.pdf")
ggsave(outlier_dfbeta, file = "./plot/d.outlier_dfbeta.png")
```

It's also possible to check outliers by visualizing the influence of each point, in terms of DFBETA - the impact on the coefficient of covariates in the model were that specific point to be removed from the data set. In general, we can identify the observations with positive and negative DFBETAs. Comparing the magnitudes of the largest dfbeta values to the regression coefficients suggests that none of the observations is terribly influential individually, even though some of the dfbeta values for extent are large compared with the others.

4.3 Corrections for violation of the PH Assumption

```
colon.death.inter <- colon.death %>%
  mutate(rxt = as.numeric(rx)*log(time),
  differt = as.numeric(differ)*log(time),
  extentt = as.numeric(extent)*log(time),
  surgt = as.numeric(surg)*log(time),
  node4t = as.numeric(node4)*log(time),
  obstructt = as.numeric(obstruct)*log(time))

d.model.inter <- coxph(Surv(time, status) ~ obstruct + differ + extent + surg + node4 + rx + obstructt +

summary(d.model.inter)
```

```
## Call:
## coxph(formula = Surv(time, status) ~ obstruct + differ + extent +
##     surg + node4 + rx + obstructt + differt + extentt + rxt +
##     node4t + surgt, data = colon.death.inter)
##
##   n= 906, number of events= 441
##
##                 coef  exp(coef)   se(coef)       z Pr(>|z|)
## obstruct1  4.306e+00  7.411e+01  1.314e+00   3.276  0.00105 **
## differ2    1.027e+01  2.882e+04  1.473e+00   6.973 3.10e-12 ***
## differ3    1.957e+01  3.167e+08  2.743e+00   7.137 9.57e-13 ***
## extent2    4.587e+01  8.324e+19  2.827e+00  16.225  < 2e-16 ***
## extent3    8.849e+01  2.697e+38  5.455e+00  16.221  < 2e-16 ***
## extent4    1.237e+02  5.296e+53  7.492e+00  16.511  < 2e-16 ***
## surg1      7.629e+00  2.057e+03  1.302e+00   5.857 4.70e-09 ***
## node41     5.247e+00  1.900e+02  1.244e+00   4.218 2.47e-05 ***
## rx2        1.913e+00  6.776e+00  6.925e-01   2.763  0.00573 **
## rx3        3.773e+00  4.350e+01  1.367e+00   2.760  0.00579 **
## obstructt -6.361e-01  5.293e-01  2.030e-01  -3.133  0.00173 **
## differt   -1.453e+00  2.338e-01  2.033e-01  -7.149 8.77e-13 ***
## extentt   -5.784e+00  3.076e-03  3.535e-01 -16.361  < 2e-16 ***
## rxt       -2.967e-01  7.433e-01  1.001e-01  -2.965  0.00303 **
## node4t    -7.774e-01  4.596e-01  1.882e-01  -4.131 3.61e-05 ***
## surgt     -1.123e+00  3.252e-01  1.952e-01  -5.756 8.61e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##           exp(coef) exp(-coef) lower .95 upper .95
## obstruct1 7.411e+01  1.349e-02 5.637e+00 9.744e+02
## differ2   2.882e+04  3.470e-05 1.608e+03 5.167e+05
## differ3   3.167e+08  3.158e-09 1.466e+06 6.843e+10
## extent2   8.324e+19  1.201e-20 3.265e+17 2.122e+22
## extent3   2.697e+38  3.708e-39 6.128e+33 1.187e+43
## extent4   5.296e+53  1.888e-54 2.221e+47 1.263e+60
## surg1     2.057e+03  4.862e-04 1.602e+02 2.641e+04
## node41    1.900e+02  5.263e-03 1.659e+01 2.176e+03
## rx2       6.776e+00  1.476e-01 1.744e+00 2.633e+01
## rx3       4.350e+01  2.299e-02 2.984e+00 6.342e+02
## obstructt 5.293e-01  1.889e+00 3.556e-01 7.881e-01
```

```
## differt   2.338e-01  4.276e+00 1.570e-01 3.483e-01
## extentt   3.076e-03  3.251e+02 1.538e-03 6.150e-03
## rxt       7.433e-01  1.345e+00 6.109e-01 9.043e-01
## node4t    4.596e-01  2.176e+00 3.179e-01 6.646e-01
## surgt     3.252e-01  3.075e+00 2.218e-01 4.767e-01
##
## Concordance= 0.986  (se = 0.002 )
## Likelihood ratio test= 3120  on 16 df,   p=<2e-16
## Wald test            = 584.1  on 16 df,   p=<2e-16
## Score (logrank) test = 2559  on 16 df,   p=<2e-16
```

```
anova(d.model.inter)
```

```
## Analysis of Deviance Table
##  Cox model: response is Surv(time, status)
## Terms added sequentially (first to last)
##
##            loglik     Chisq Df Pr(>|Chi|)
## NULL      -2847.5
## obstruct  -2845.2    4.7665  1  0.0290194 *
## differ    -2837.4   15.4677  2  0.0004378 ***
## extent    -2826.6   21.5515  3  8.086e-05 ***
## surg      -2824.6    3.9913  1  0.0457345 *
## node4     -2786.1   77.0443  1  < 2.2e-16 ***
## rx        -2780.3   11.5302  2  0.0031351 **
## obstructt -1904.1 1752.5175  1  < 2.2e-16 ***
## differt   -1641.7  524.8644  1  < 2.2e-16 ***
## extentt   -1315.8  651.7571  1  < 2.2e-16 ***
## rxt       -1311.2    9.0697  1  0.0025988 **
## node4t    -1304.8   12.8056  1  0.0003456 ***
## surgt     -1287.5   34.7200  1  3.807e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Based on the test interaction for proportionality, the result shows that all the interactions of covaraites with 'log(time)' are significant (i.e., less than 0.05). Therefore, we can include these interactions with function of time as the method of PH assumption verification and solution to its violation.

4.4 Final model

With the inclusion of treatment, our final model is given by: Surv(time, status) ~ obstruct + differ + extent + surg + node4 + rx + obstructt + differt + extentt + surgt + rxt + node4t.

```
d.final.model <- coxph(Surv(time, status) ~ obstruct + differ + extent + surg + node4 + rx + obstructt +
summary(d.final.model)
```

```
## Call:
## coxph(formula = Surv(time, status) ~ obstruct + differ + extent +
##     surg + node4 + rx + obstructt + differt + extentt + rxt +
##     node4t + surgt, data = colon.death.inter)
```

```
##
##   n= 906, number of events= 441
##
##                 coef  exp(coef)   se(coef)       z Pr(>|z|)
## obstruct1  4.306e+00  7.411e+01  1.314e+00   3.276  0.00105 **
## differ2    1.027e+01  2.882e+04  1.473e+00   6.973 3.10e-12 ***
## differ3    1.957e+01  3.167e+08  2.743e+00   7.137 9.57e-13 ***
## extent2    4.587e+01  8.324e+19  2.827e+00  16.225  < 2e-16 ***
## extent3    8.849e+01  2.697e+38  5.455e+00  16.221  < 2e-16 ***
## extent4    1.237e+02  5.296e+53  7.492e+00  16.511  < 2e-16 ***
## surg1      7.629e+00  2.057e+03  1.302e+00   5.857 4.70e-09 ***
## node41     5.247e+00  1.900e+02  1.244e+00   4.218 2.47e-05 ***
## rx2        1.913e+00  6.776e+00  6.925e-01   2.763  0.00573 **
## rx3        3.773e+00  4.350e+01  1.367e+00   2.760  0.00579 **
## obstructt -6.361e-01  5.293e-01  2.030e-01  -3.133  0.00173 **
## differt   -1.453e+00  2.338e-01  2.033e-01  -7.149 8.77e-13 ***
## extentt   -5.784e+00  3.076e-03  3.535e-01 -16.361  < 2e-16 ***
## rxt       -2.967e-01  7.433e-01  1.001e-01  -2.965  0.00303 **
## node4t    -7.774e-01  4.596e-01  1.882e-01  -4.131 3.61e-05 ***
## surgt     -1.123e+00  3.252e-01  1.952e-01  -5.756 8.61e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##           exp(coef) exp(-coef) lower .95 upper .95
## obstruct1 7.411e+01  1.349e-02 5.637e+00 9.744e+02
## differ2   2.882e+04  3.470e-05 1.608e+03 5.167e+05
## differ3   3.167e+08  3.158e-09 1.466e+06 6.843e+10
## extent2   8.324e+19  1.201e-20 3.265e+17 2.122e+22
## extent3   2.697e+38  3.708e-39 6.128e+33 1.187e+43
## extent4   5.296e+53  1.888e-54 2.221e+47 1.263e+60
## surg1     2.057e+03  4.862e-04 1.602e+02 2.641e+04
## node41    1.900e+02  5.263e-03 1.659e+01 2.176e+03
## rx2       6.776e+00  1.476e-01 1.744e+00 2.633e+01
## rx3       4.350e+01  2.299e-02 2.984e+00 6.342e+02
## obstructt 5.293e-01  1.889e+00 3.556e-01 7.881e-01
## differt   2.338e-01  4.276e+00 1.570e-01 3.483e-01
## extentt   3.076e-03  3.251e+02 1.538e-03 6.150e-03
## rxt       7.433e-01  1.345e+00 6.109e-01 9.043e-01
## node4t    4.596e-01  2.176e+00 3.179e-01 6.646e-01
## surgt     3.252e-01  3.075e+00 2.218e-01 4.767e-01
##
## Concordance= 0.986  (se = 0.002 )
## Likelihood ratio test= 3120  on 16 df,   p=<2e-16
## Wald test            = 584.1  on 16 df,   p=<2e-16
## Score (logrank) test = 2559  on 16 df,   p=<2e-16
```

From the results of the summary function for the final mortality model, we see that after we control for all other covariates in the model the coefficient for covariate rxLev is -0.031, which indicates a protective effect. And the hazard rate of death for the group treated with rxlev is 3% less than observation group, with a p-value of 0.78. Furthermore, the confidence interval for the hazard ratio is (0.78, 1.21).

On the other hand, the coefficient for covariate rxLev+5Fu is -0.36, which indicates a protective effect. And the hazard rate of death for the group treated with rxLev+5Fu is 32.2% less than observation group, with a p-value of 0.003. Furthermore, the confidence interval for the hazard ratio is (0.55, 0.89).

5. Discussion

We can now observe whether treatments Levamisole and Levamisole+5-FU help improve the survival rate in colon cancer patients from negative coefficients of different treatment groups. Our result indicates that the hazard rate for the group treated with Levamisole is 97% of what it is for the observation group. Since the p-value for the coefficient is 0.78 which is greater than 0.05, there is no significant evidence to indicate a difference between the hazard rate of the group treated with Levamisole and the hazard rate of the observation group. Therefore, we conclude that the treatment Levamisole is not effective on improving the survival probability in colon cancer patients. On the other hand, our result indicates that the hazard rate for the group treated with Levamisole+5-FU is 67.8% of the hazard rate for the observation group. Since the p-value for the coefficient is close to 0, this indicates that there is a significant difference between the hazard rate of the group treated with Levamisole+5-FU and the hazard rate for the observation group. Therefore, we conclude that the treatment Levamisole+5-FU is effective on improving the survival rate in colon cancer patients. There is a 32.2% chance that patients who received the treatment Levamisole+5-FU survive longer than patients who do not receive any treatments and patients who received Levamisole alone.