homework1

Question #1a, 3.2

3.2 A large number of disease-free individuals were enrolled in a study beginning January 1, 1970, and were followed for 30 years to assess the age at which they developed breast cancer. Individuals had clinical exams every 3 years after enrollment. For four selected individuals described below, discuss in detail, the types of censoring and truncation that are represented.

(a) A healthy individual, enrolled in the study at age 30, never developed breast cancer during the study.

a. type I, right censored since event did not occur prior to some prespecified time

(b) A healthy individual, enrolled in the study at age 40, was diagnosed with breast cancer at the fifth exam after enrollment (i.e., the disease started sometime between 12 and 15 years after enrollment).

b. interval censoring since event time is only known to occur between some interval follow up times

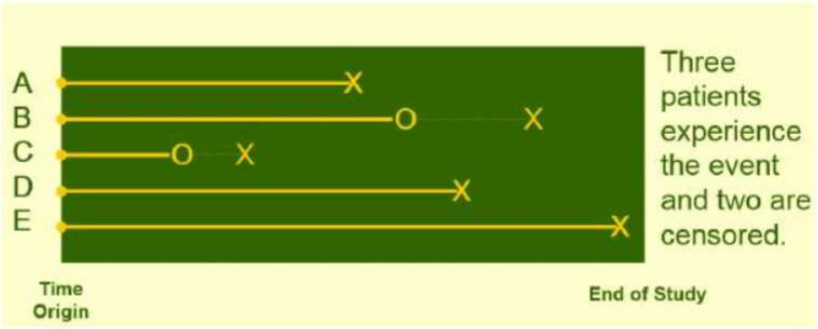
(c) A healthy individual, enrolled in the study at age 50, died from a cause unrelated to the disease (i.e., not diagnosed with breast cancer at any time during the study) at age 61.

c. Here if we assume the death was unrelated to breast cancer then is likely random censoring since the time at which the patient would have died from breast cancer is unknown

Random censoring:

before had fixed censoring, in type I and type II it looked like the investigator had a little bit of control over the type of censoring in real life people may be lost (e.g. move, lost to f/u etc..)

Random censoring occurs when follow-up is terminated for reasons that are not under the control of the investigator. (e.g. withdrawals, loss to follow-up)



some may be lost to f/u or withdrew 2/2 various reasons

In most studies of interest, the censoring scheme is a combination of random and Type I censoring:

real life has both types

- Some patients are lost to follow-up during the study and become randomly censored

their censoring time can be thought of as a random variable

- Other patients may be type I censored when the study period ends

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(d) An individual, enrolled in the study at age 42, moved away from the community at age 55 and was never diagnosed with breast cancer during the period of observation.

d. This again seems to be random censoring since patient dropped out of study with no apparent reasons related to the disease process of breast cancer.

(e) Confining your attention to the four individuals described above, write down the likelihood for this portion of the study.

e. Likelihood for four observations would be the product of the four likelihoods using the constructed likelihood function
obs 1; i=1

$$L = \prod_{i=1}^{n} [h(t_i)]^{\delta_i} \exp[-H(t_i)]$$

$[h(t_1)]\exp[-H(t_1)]$

obs 2; i=2

$$\prod_{i \varepsilon I} [S_i(L_i) - S_i(R_i)]$$

$1-[h(t_2)]\exp[-H(t_2)]-[h(t_2)]\exp[-H(t_2)]$

obs 3; i=3
Textbook section 3.5 example 3.10 seems to suggest that the formula for random censoring is:

$$L \propto \prod_{i=1}^{n} [f(t_i)]^{\delta_i} [S(t_i)]^{1-\delta_i}. \qquad (3.5.6)$$

which appears nearly identical to that for right censoring

$$L \propto \prod_{i=1}^{n} [f_i(t)]^{\delta} [S_i(t)]^{1-\delta}$$

however the lecture notes mention that for right censoring we use fi not f
So for random censoring do we use
f(t3) or f3(t) or are they the same

Assuming the same then random censoring seems similar to right censoring for the calculation

$[h(t_3)]\exp[-H(t_3)]$

This is further backed up by lecture notes

Does Type of Censoring Affect Survival Methods?

- Standard methods of survival analysis do not distinguish among Type I, Type II, or Random censoring theory behind this is explained in pages 75-77 of textbook
- With Type I or Type II censoring, standard methods are not biased
- The analytic tools we will use assume that, if random censoring occurs, it is *non-informative* or unrelated to the reason for failure.

make assumption in our class that random censoring may occur but it is not related to the cause of failure, if it does contribute then need more sophisticated form of analysis

obs 4; i=4

$[h(t_4)]exp[-H(t_4)]$

Thus, for e the final likelihood is:

$[h(t_1)]exp[-H(t_1)] * 1-[h(t_2)]exp[-H(t_2)]-[h(t_2)]exp[-H(t_2)] * [h(t_3)]exp[-H(t_3)] * [h(t_4)]exp[-H(t_4)]$

Question #1b, 3.3

3.3 An investigator, performing an animal study designed to evaluate the effects of vegetable and vegetable-fiber diets on mammary carcinogenesis risk, randomly assigned female Sprague-Dawley rats to five dietary groups (control diet, control diet plus vegetable mixture, 1; control diet plus vegetable mixture, 2; control diet plus vegetable-fiber mixture, 1; and control diet plus vegetable-fiber mixture, 2). Mammary tumors were induced by a single oral dose (5 mg dissolved in 1.0 ml. corn oil) of 7,12-dimethylbenz(α)anthracene (DMBA) administered by intragastric intubation, i.e., the starting point for this study is when DMBA was given.

Starting 6 weeks after DMBA administration, each rat was examined once weekly for 14 weeks (post DMBA administration) and the time (in days) until onset of the first palpable tumor was recorded. We wish to make an inference about the marginal distribution of the time until a tumor is detected. Describe, in detail, the types of censoring that are represented by the following rats.

(a) A rat who had a palpable tumor at the first examination at 6 weeks after intubation with DMBA.

Left censoring since to have a palpable tumor carcinogenesis must have been occurring before the DBMA was administered.
The definition of left censoring is that the event of interest occurred before the study started but it is unknown when the event occurred

(b) A rat that survived the study without having any tumors.

Right censored since we only know that the subject did not have the event during the observation period

(c) A rat which did not have a tumor at week 12 but which had a tumor at week 13 after inturbation with DMBA.

Interval censoring since the event occurred between follow-up time points but it is not clear at what point between 12 and 13 weeks post DMBA administration when the tumor development occurred

(d) A rat which died (without tumor present and death was unrelated to the occurrence of cancer) at day 37 after intubation with DMBA.

Random censoring since the death of the subject is not though to be related to the disease process of tumor formation. The time that the subject would have developed the tumor is unknown

(e) Confining our attention to the four rats described above, write down the likelihood for this portion of the study.

obs 1; i=1

$$(1 - S_i(C_i))$$

$1-[h(t_1)]exp[-H(t_1)]$

obs 2; i=2

$$L = \prod_{i=1}^{n} [b(t_i)]^{\delta_i} \exp[-H(t_i)]$$

$[h(t_2)]exp[-H(t_2)]$

obs 3; i=3

$$\prod_{i \varepsilon I} [S_i(L_i) - S_i(R_i)]$$

$1-[h(t_3)]exp[-H(t_3)]-[h(t_3)]exp[-H(t_3)]$

obs 4; i=4

As mentioned before, the textbook section 3.5 example 3.10 seems to suggest that the formula for random censoring is

$$L \propto \prod_{i=1}^{n} [f(t_i)]^{\delta_i} [S(t_i)]^{1-\delta_i}. \qquad (3.5.6)$$

$[h(t_4)]exp[-H(t_4)]$

Thus for e the final likelihood is:

$1-[h(t_1)]\exp[-H(t_1)]*[h(t_2)]\exp[-H(t_2)]* 1-[h(t_3)]\exp[-H(t_3)]-[h(t_3)]\exp[-H(t_3)]*[h(t_4)]\exp[-H(t_4)]$

Question #1c, 3.6 a

3.6 The following data consists of the times to relapse and the times to death following relapse of 10 bone marrow transplant patients. In the sample patients 4 and 6 were alive in relapse at the end of the study and patients 7–10 were alive, free of relapse at the end of the study. Suppose the time to relapse had an exponential distribution with hazard rate λ and the time to death in relapse had a Weibull distribution with parameters θ and α.

Patient	Relapse Time (months)	Death Time (months)
1	5	11
2	8	12
3	12	15
4	24	33^+
5	32	45
6	17	28^+
7	16^+	16^+
8	17^+	17^+
9	19^+	19^+
10	30^+	30^+

$^+$ Censored observation

(a) Construct the likelihood for the relapse rate λ.

D= # that relapsed during study period = 6
PT = total time in months = 180
Likelihood for relapse rate

$$\hat{\lambda} = \frac{D}{PT}$$

> sum(c(5,8,12,24,32,17,16,17,19,30))
[1] 180
Thus lambda_hat = D/PT = 6/180=0.0333/month

Question #1d

Give examples of right censored, left censored, interval-censored, left-truncated data from your field of study. These examples should not be from the Klein & Moeschberger textbook or from the video lectures.

Agriculture is an industry which I grew up in and remain interested in so am providing examples from this context

Right censored
An example of right censored observations in agriculture could be time to hybrid seed germination where at the end of the study some seeds with specific hybrid genotypes have not germinated.
Left censored
Study at what age calves wean from their mothers with a bull present in the herd but find that at time of study initiation some calves have already weaned from their mother but don't know when.
Left truncated
Study at what age vaccinated animals become infected where animals randomly enter the study at different ages and times.
Interval censured
Visit orchards every two weeks to study at what age trees first produce fruit and find trees which produced between previous and current visit but do not know exactly when produced between those timepoints.

Question #2

Researchers wish to explore the efficacy of triple-drug combinations of antiretroviral therapy for treatment of HIV-infected patients. Because of limitations on potency and the continuing emergence of drug resistance seen with the use of currently available antiretroviral agents in monotherapy and two-drug regimens, triple combination regimens should represent a more promising approach to maximize antiviral activity, maintain long-term efficacy, and reduce the incidence of drug resistance. Towards this end, investigators performed a randomized study comparing AZT + zalcitabine (ddC) versus AZT + zalcitabine (ddC) + saquinavir. The data, time from administration of treatment (in days) until the CD4 count reached a pre-specified level, is given below for the two groups:

AZT + zalcitabine (ddC):
4+, 6, 11, 12, 32, 35, 38+, 39, 45, 49, 75, 80, 84, 85, 87, 102, 180+

AZT + zalcitabine (ddC) + saquinivir:
2, 3, 4, 12, 22, 48, 51+, 56+, 80, 85, 90, 94+, 160, 171, 180, 180+, 238

a. For both groups separately, construct a data layout (similar to what was done in lecture slides) containing the unique, ordered event times, the number of events that occurred at those unique event times, the number of censored observations in the relevant interval, the number in the risk set at that time, and the Kaplan-Meier estimate of the survival curve at that time. What is the median survival time in the two groups? Will you be comfortable reporting the mean survival time in the two groups?

a) KM table using custom function in R for azt_ddc group

	orderedEventTimes_tj	eventsAtEventTime_ej	censoredObservationsInInterval_cj	inRiskSetAtTime_nj	kaplanMeirSurvivalCurveAtTime_s_tj-1	c_tj-1	kaplanMeirSurvivalCurveAtTime_s_tj
1	0	0	0	17	-	17/17	1
2	6	1	0	16	1	15/16	0.938
3	11	1	0	15	0.938	14/15	0.875
4	12	1	0	14	0.875	13/14	0.812
5	32	1	0	13	0.812	12/13	0.75
6	35	1	0	12	0.75	11/12	0.688
7	39	1	0	10	0.688	9/10	0.619
8	45	1	0	9	0.619	8/9	0.55
9	49	1	0	8	0.55	7/8	0.481
10	75	1	0	7	0.481	6/7	0.412
11	80	1	0	6	0.412	5/6	0.343
12	84	1	0	5	0.343	4/5	0.274
13	85	1	0	4	0.274	3/4	0.206
14	87	1	0	3	0.206	2/3	0.137
15	102	1	0	2	0.137	1/2	0.068

b) KM table using built in function in R for azt_ddc group

```
## Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc, fixed = TRUE)),
##     ifelse(grepl("+", azt_ddc, fixed = TRUE), 0, 1)) ~ 1, conf.type = "log-log")
##
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     6     16       1   0.9375  0.0605      0.63235        0.991
##    11     15       1   0.8750  0.0827      0.58598        0.967
##    12     14       1   0.8125  0.0976      0.52460        0.935
##    32     13       1   0.7500  0.1083      0.46343        0.898
##    35     12       1   0.6875  0.1159      0.40460        0.856
##    39     10       1   0.6188  0.1230      0.33929        0.808
##    45      9       1   0.5500  0.1271      0.27933        0.756
##    49      8       1   0.4813  0.1285      0.22410        0.699
##    75      7       1   0.4125  0.1272      0.17339        0.639
##    80      6       1   0.3438  0.1232      0.12728        0.575
##    84      5       1   0.2750  0.1162      0.08617        0.507
```

```
##     85       4        1   0.2063  0.1055       0.05082         0.433
##     87       3        1   0.1375  0.0900       0.02265         0.354
##    102       2        1   0.0688  0.0662       0.00443         0.267
```

Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc, fixed = TRUE)),
ifelse(grepl("+", azt_ddc, fixed = TRUE), 0, 1)) ~ 1, conf.type = "log-log")
n events median 0.95LCL 0.95UCL
17 14 **49** 32 85

median of 49

The median survival time is defined as the time at t such that S(t) = 1/2. For AZT + DDC it is **49.**

a) KM table using custom function in R for azt_ddc_saq group

	orderedEventTimes_tj	eventsAtEventTime_ej	censoredObservationsInInterval_cj	inRiskSetAtTime_nj	kaplanMeirSurvivalCurveAtTime_s_tj-1	c_tj-1	kaplanMeirSurvivalCurveAtTime
1	0	0	0	17	-	17/17	1
2	2	1	0	17	1	16/17	0.941
3	3	1	0	16	0.941	15/16	0.882
4	4	1	0	15	0.882	14/15	0.823
5	12	1	0	14	0.823	13/14	0.764
6	22	1	0	13	0.764	12/13	0.705
7	48	1	0	12	0.705	11/12	0.646
8	51	1	0	11	0.646	10/11	0.587
9	56	1	0	10	0.587	9/10	0.528
10	80	1	0	9	0.528	8/9	0.469
11	85	1	0	8	0.469	7/8	0.41
12	90	1	0	7	0.41	6/7	0.351
13	94	1	0	6	0.351	5/6	0.292
14	160	1	0	5	0.292	4/5	0.234
15	171	1	0	4	0.234	3/4	0.176
16	180	2	0	3	0.176	1/3	0.059
17	238	1	0	1	0.059	0/1	0

b) KM table using built in function in R for azt_ddc_saq

```
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     2     17       1   0.9412  0.0571      0.65018         0.991
##     3     16       1   0.8824  0.0781      0.60598         0.969
```

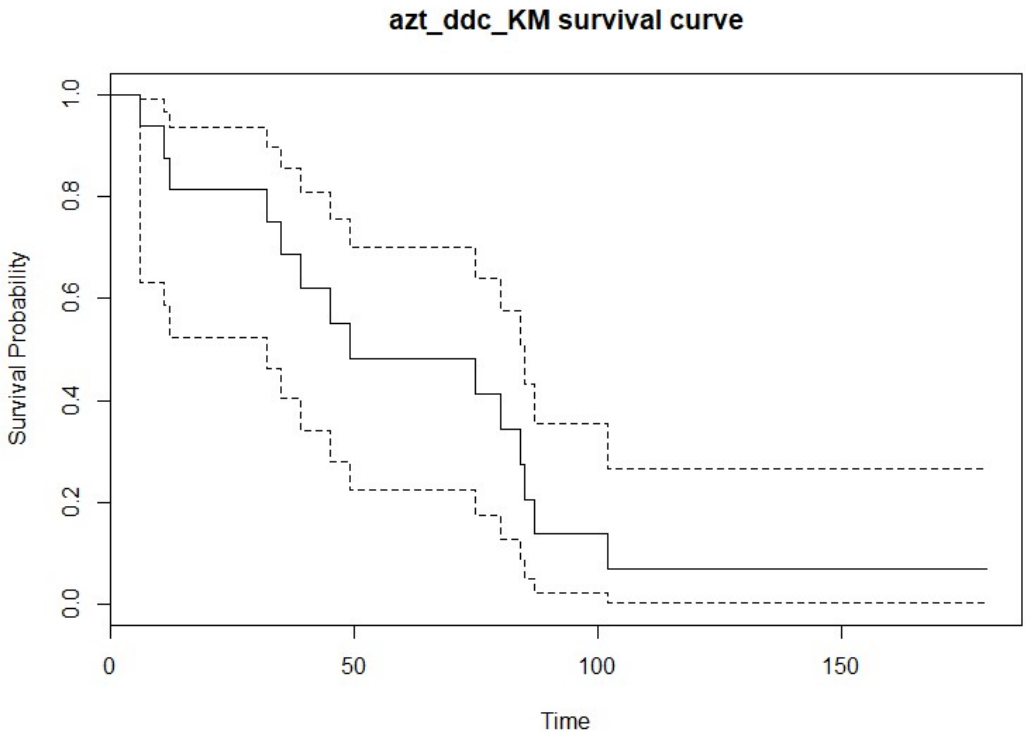
```
##      4      15         1   0.8235  0.0925       0.54713         0.939
##     12      14         1   0.7647  0.1029       0.48828         0.904
##     22      13         1   0.7059  0.1105       0.43148         0.866
##     48      12         1   0.6471  0.1159       0.37715         0.823
##     51      11         1   0.5882  0.1194       0.32537         0.778
##     56      10         1   0.5294  0.1211       0.27617         0.730
##     80       9         1   0.4706  0.1211       0.22960         0.680
##     85       8         1   0.4118  0.1194       0.18576         0.626
##     90       7         1   0.3529  0.1159       0.14483         0.570
##     94       6         1   0.2941  0.1105       0.10712         0.511
##    160       5         1   0.2353  0.1029       0.07308         0.449
##    171       4         1   0.1765  0.0925       0.04348         0.383
##    180       3         2   0.0588  0.0571       0.00391         0.235
##    238       1         1   0.0000     NaN            NA            NA
```

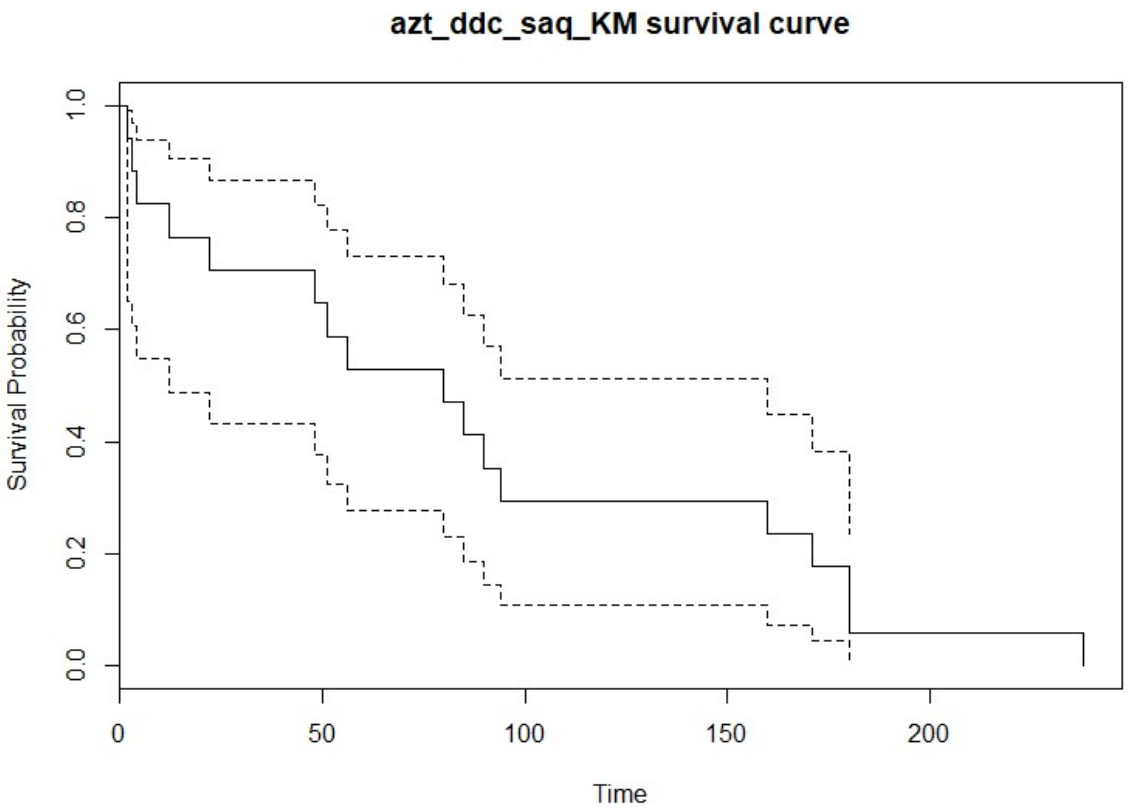
```
n  events  median 0.95LCL 0.95UCL
   17     17     80     12     160
```

median of 80

If the survival curve is not continuous at 1/2 (if the survival function is a step function, for example), then the median is taken to be the smallest t such that S(t)<=1/2. Thus for AZT + DDC + SAQ the median survival would be 80.

The **mean** survival time is only defined if the survival curve goes to zero that is S(inf)=0. Thus, if the last subject is in the study is censored then the survival function will not go to 0 and the area under the curve cannot be calculated. In other words, and in theory, the mean survival cannot be computed when the Kaplan-Meier survival curve does not reach zero. Therefore, I would not feel comfortable reporting the mean for the azt_ddc group since the last observation is censored. I would feel more comfortable reporting the mean survival time in the azt_ddc_saq group since the last observation is not censored and the survival function does go to zero.


azt_ddc_KM survival curve
Survival Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
Time

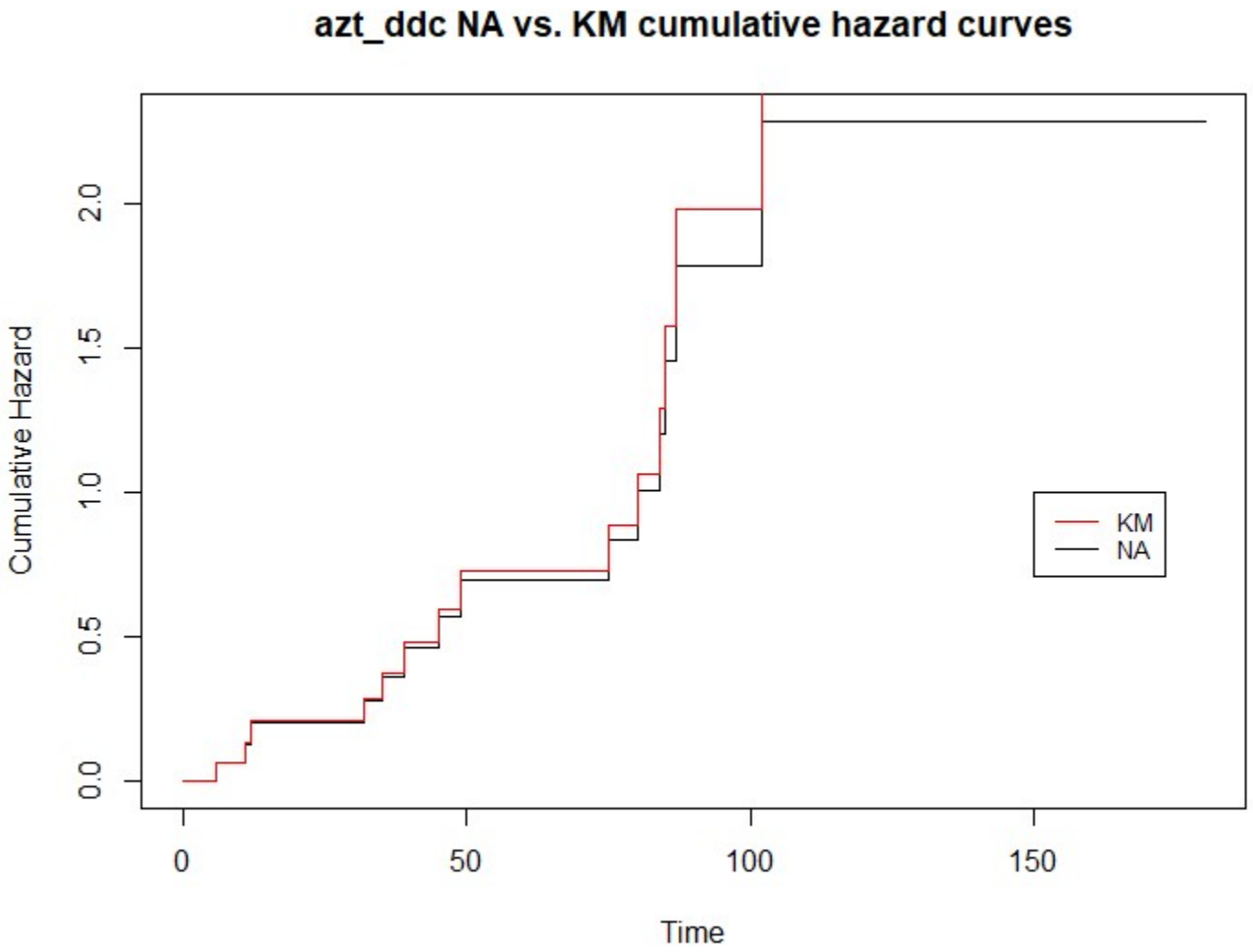


c. For any one group, compute the Nelson Aalen estimates of the cumulative hazard function. Graphically compare $\widehat{H}(t)$ versus $\widetilde{H}(t)$ and comment on this comparison.

cumulative hazard times using Nelson-Aalen technique for azt_ddc group

orderedEventTimes_tj	eventsAtEventTime_ej	inRiskSetAtTime_nj	cumulativeHazardRate_ht
0	0	17	0

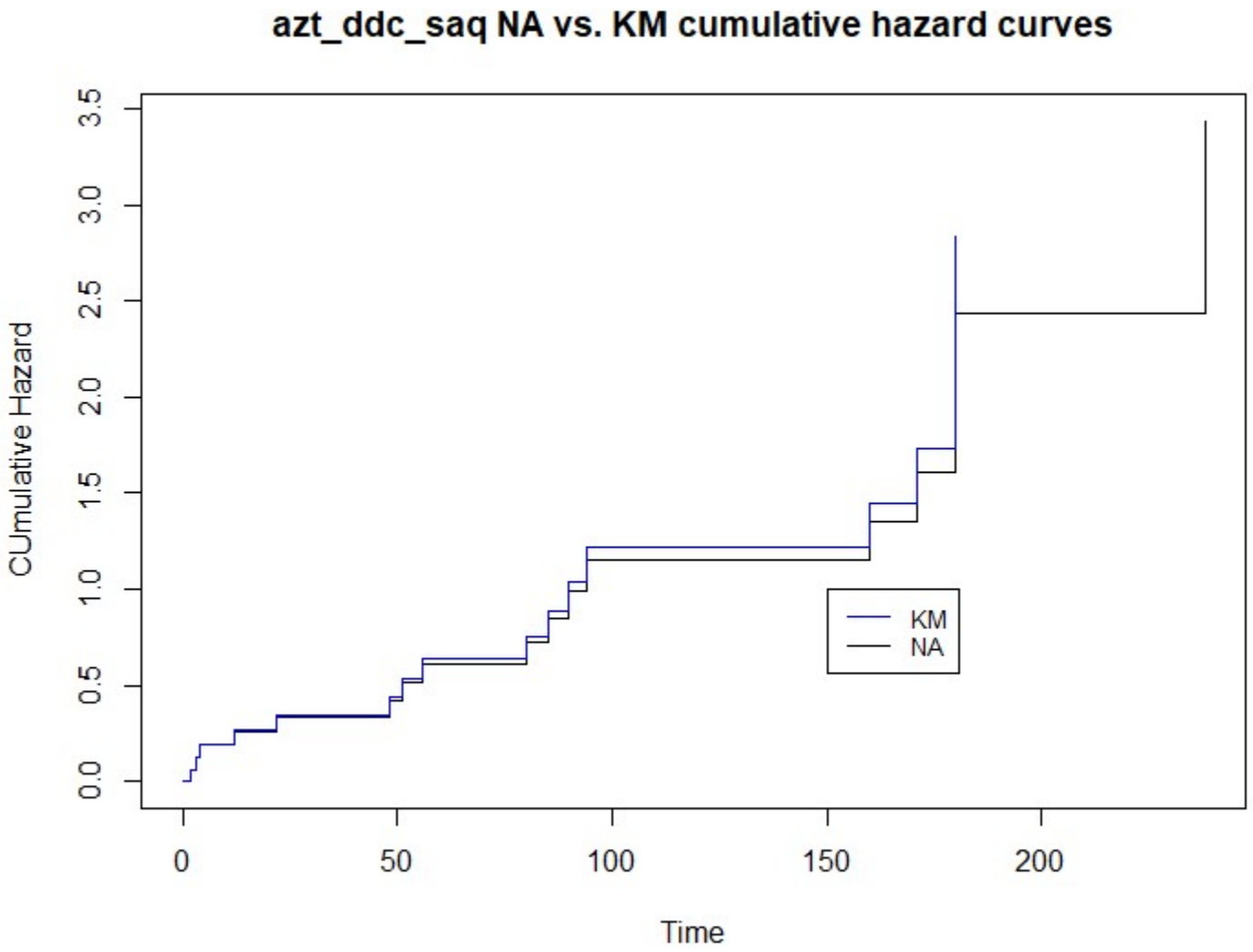
6	1	16	0.062
11	1	15	0.129
12	1	14	0.2
32	1	13	0.277
35	1	12	0.36
39	1	10	0.46
45	1	9	0.571
49	1	8	0.696
75	1	7	0.839
80	1	6	1.006
84	1	5	1.206
85	1	4	1.456
87	1	3	1.789
102	1	2	2.289



As described in the lecture and text the Nelson-Aalen technique underestimates hazard and overestimates survival compared to the Kaplan-Meier technique

Cumulative hazard times using Nelson-Aalen technique for azt_ddc_saq group

orderedEventTimes_tj	eventsAtEventTime_ej	inRiskSetAtTime_nj	cumulativeHazardRate_ht
2	1	17	0.059
3	1	16	0.122
4	1	15	0.189
12	1	14	0.26
22	1	13	0.337
48	1	12	0.42
51	1	11	0.511
56	1	10	0.611
80	1	9	0.722
85	1	8	0.847
90	1	7	0.99
94	1	6	1.157
160	1	5	1.357
171	1	4	1.607
180	2	3	2.274
238	1	1	3.274



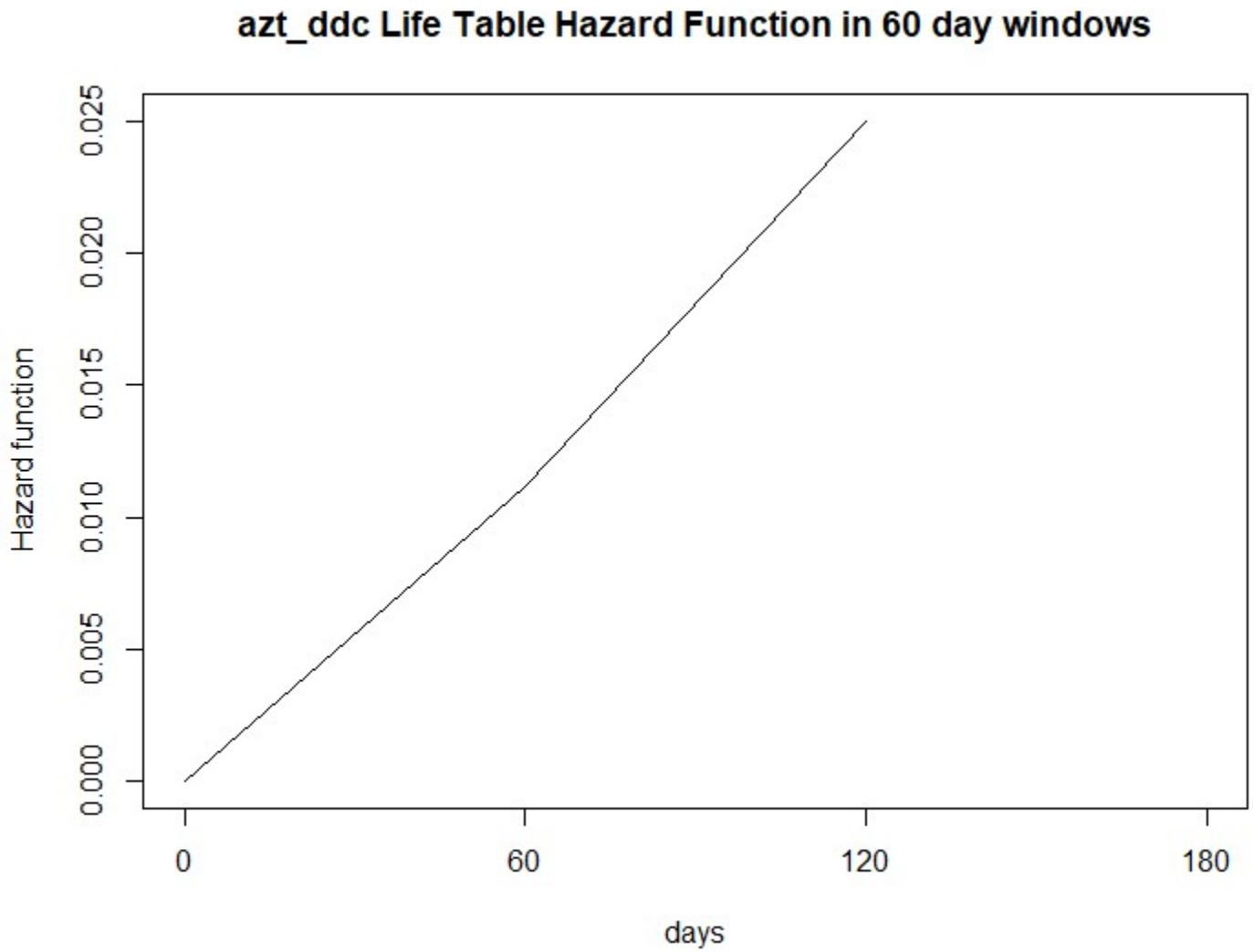
Again as described in the lecture and text, the Nelson-Aalen technique underestimates hazard and overestimates survival compared to the Kaplan-Meier technique

d. Use **PROC LIFETEST** to produce the Life-Table estimate of the survival function and to plot the life-table estimates of the hazard function based on interval widths of 60 days. What does this tell you about the hazard function for the two groups?

Used R function *"lifetab"* to create table and graphs below instead of PROC LIFETEST

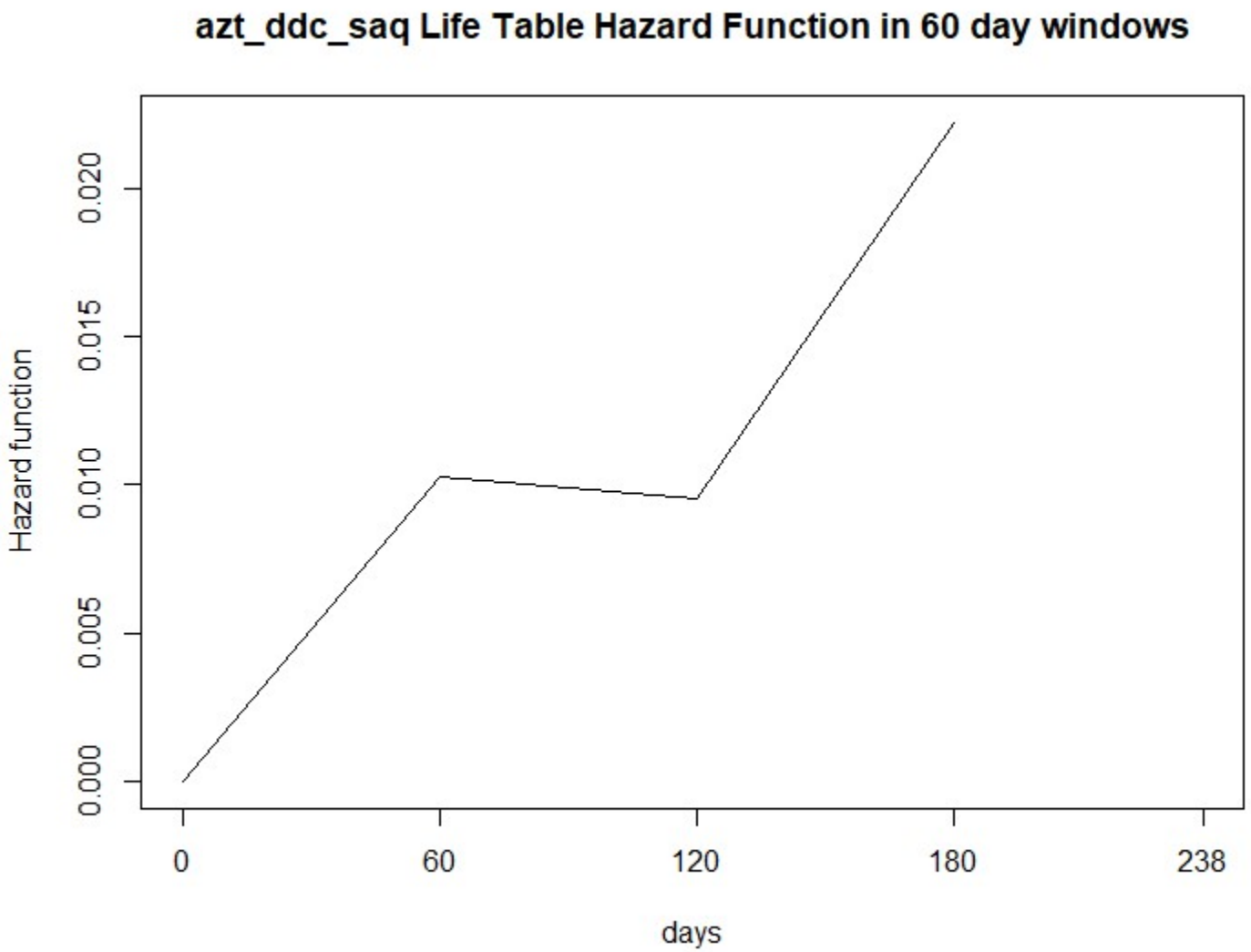
life-table azt_ddc

	nsubs	nlost	nrisk	nevent	surv	pdf	hazard
0-4	17	1	16.5	0	1.00000	0.000000000	0.00000000
4-6	16	0	16.0	1	1.00000	0.031250000	0.03225806
6-11	15	0	15.0	1	0.93750	0.012500000	0.01379310
11-12	14	0	14.0	1	0.87500	0.062500000	0.07407407
12-32	13	0	13.0	1	0.81250	0.003125000	0.00400000
32-35	12	0	12.0	1	0.75000	0.020833333	0.02898551
35-38	11	1	10.5	0	0.68750	0.000000000	0.00000000
38-39	10	0	10.0	1	0.68750	0.068750000	0.10526316
39-45	9	0	9.0	1	0.61875	0.011458333	0.01960784
45-49	8	0	8.0	1	0.55000	0.017187500	0.03333333
49-75	7	0	7.0	1	0.48125	0.002644231	0.00591716
75-80	6	0	6.0	1	0.41250	0.013750000	0.03636364
80-84	5	0	5.0	1	0.34375	0.017187500	0.05555556
84-85	4	0	4.0	1	0.27500	0.068750000	0.28571429
85-87	3	0	3.0	1	0.20625	0.034375000	0.20000000
87-102	2	0	2.0	1	0.13750	0.004583333	0.04444444



life-table azt_ddc_saq

	nsubs	nlost	nrisk	nevent	surv	pdf	hazard	se.surv	se.pdf	se.hazard
0-2	17	0	17	1	1.0000000	0.0294117647	0.030303030	0.00000000	0.0285336029	0.030289114
2-3	16	0	16	1	0.9411765	0.0588235294	0.064516129	0.05706721	0.0570672059	0.064482553
3-4	15	0	15	1	0.8823529	0.0588235294	0.068965517	0.07814249	0.0570672059	0.068924503
4-12	14	0	14	1	0.8235294	0.0073529412	0.009259259	0.09245944	0.0071334007	0.009252906
12-22	13	0	13	1	0.7647059	0.0058823529	0.008000000	0.10287937	0.0057067206	0.007993597
22-48	12	0	12	1	0.7058824	0.0022624434	0.003344482	0.11051017	0.0021948925	0.003341319
48-51	11	0	11	1	0.6470588	0.0196078431	0.031746032	0.11590404	0.0190224020	0.031710018
51-56	10	0	10	1	0.5882353	0.0117647059	0.021052632	0.11936462	0.0114134412	0.021023453
56-80	9	0	9	1	0.5294118	0.0024509804	0.004901961	0.12105782	0.0023778002	0.004893473
80-85	8	0	8	1	0.4705882	0.0117647059	0.026666667	0.12105782	0.0114134412	0.026607341
85-90	7	0	7	1	0.4117647	0.0117647059	0.030769231	0.11936462	0.0114134412	0.030678062
90-94	6	0	6	1	0.3529412	0.0147058824	0.045454545	0.11590404	0.0142668015	0.045266327
94-160	5	0	5	1	0.2941176	0.0008912656	0.003367003	0.11051017	0.0008646546	0.003346155
160-171	4	0	4	1	0.2352941	0.0053475936	0.025974026	0.10287937	0.0051879278	0.025707619
171-180	3	0	3	2	0.1764706	0.0130718954	0.111111111	0.09245944	0.0086824989	0.068041382



The life table plots demonstrate that the addition of the anti-retroviral medication Saquinavir reduces the hazard function of death when compared to the group with only two medications azt and ddc

e. For any one group, use **PROC LIFETEST** to produce 95% confidence intervals and 95% confidence band using the various approaches you learned in class. Comment on your results.

Used R functions *"survfit"* and *"confband"* to generate values below

	time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI	lower 95% CB	upper 95% CB
1	6	16	1	0.93750	0.06051536	0.82608827	1.0000000	0.643728905	1.0000000
2	11	15	1	0.87500	0.08267973	0.72707141	1.0000000	0.510922015	0.9999794
3	12	14	1	0.81250	0.09757809	0.64209217	1.0000000	0.425344054	0.9985377
4	32	13	1	0.75000	0.10825318	0.56519837	0.9952258	0.355310460	0.9924805
5	35	12	1	0.68750	0.11587810	0.49408619	0.9566271	0.295073863	0.9808050
6	39	10	1	0.61875	0.12300557	0.41908199	0.9135481	0.242188699	0.9636890
7	45	9	1	0.55000	0.12710724	0.34966048	0.8651249	0.190995454	0.9389813
8	49	8	1	0.48125	0.12847323	0.28519127	0.8120921	0.146211957	0.9084306
9	75	7	1	0.41250	0.12719172	0.22540390	0.7548949	0.107343563	0.8721711
10	80	6	1	0.34375	0.12318011	0.17030262	0.6938476	0.074193951	0.8301174
11	84	5	1	0.27500	0.11615588	0.12017052	0.6293141	0.046800569	0.7819227
12	85	4	1	0.20625	0.10551909	0.07566808	0.5621798	0.025408255	0.7268739
13	87	3	1	0.13750	0.08999783	0.03812115	0.4959517	0.010431689	0.6636443
14	102	2	1	0.06875	0.06624337	0.01040174	0.4544011	0.002239724	0.5896384

As expected the lower and upper CIs (confidence intervals) are in general tighter than the CB (confidence band)

f. Read about the *Redistribute to the Right Algorithm* given in "Theoretical Notes #2" on Page # 102 of the textbook. Then study the example workout given on Page #103. Show a similar workout for the 'AZT + zalcitabine + saquinivir' treatment group data given in the problem statement.

Act_ddc_saq

	observation	decrement	action	S_t
2	2	0.059	survival is 1-(0.0588235294117647)	0.941
3	3	0.118	survival is 1-(0.117647058823529)	0.882
4	4	0.176	survival is 1-(0.176470588235294)	0.824
5	12	0.235	survival is 1-(0.235294117647059)	0.765
6	22	0.294	survival is 1-(0.294117647058824)	0.706
7	48	0.353	survival is 1-(0.352941176470588)	0.647
8	51	0.412	survival is 1-(0.411764705882353)	0.588
9	56	0.471	survival is 1-(0.470588235294118)	0.529
10	80	0.529	survival is 1-(0.529411764705882)	0.471
11	85	0.588	survival is 1-(0.588235294117647)	0.412
12	90	0.647	survival is 1-(0.647058823529412)	0.353
13	94	0.706	survival is 1-(0.705882352941177)	0.294
14	160	0.765	survival is 1-(0.764705882352941)	0.235
15	171	0.824	survival is 1-(0.823529411764706)	0.176
16	180	0.882	survival is 1-(0.882352941176471)	0.118
17	238	0.941	survival is 1-(0.941176470588235)	0.059

In table above there were no censored values so the survival function was simply reduced by 1/n for each observation (azt_ddc_saq)

	observation	decrement	action	S_t
2	4+	0.000	next time survival is 1-(0 + 0.0588235294117647 + 0.0588...	1.000
3	6	0.062	survival is 1-(0.0625)	0.938
4	11	0.125	survival is 1-(0.125)	0.875
5	12	0.188	survival is 1-(0.1875)	0.812
6	32	0.250	survival is 1-(0.25)	0.750
7	35	0.312	survival is 1-(0.3125)	0.688
8	38+	0.000	next time survival is 1-(0.3125 + 0.0625 + 0.0625*1/10)	0.688
9	39	0.381	survival is 1-(0.38125)	0.619
10	45	0.450	survival is 1-(0.45)	0.550
11	49	0.519	survival is 1-(0.51875)	0.481
12	75	0.588	survival is 1-(0.5875)	0.412
13	80	0.656	survival is 1-(0.65625)	0.344
14	84	0.725	survival is 1-(0.725)	0.275
15	85	0.794	survival is 1-(0.79375)	0.206
16	87	0.862	survival is 1-(0.8625)	0.138
17	102	0.931	survival is 1-(0.93125)	0.069
18	180+	1.000	survival is 1-(1)	0.000

For completeness this is the output for azt_ddc without saq

4.7 Consider a hypothetical study of the mortality experience of diabetics. Thirty diabetic subjects are recruited at a clinic and followed until death or the end of the study. The subject's age at entry into the study and their age at the end of study or death are given in the table below. Of interest is estimating the survival curve for a 60- or for a 70-year-old diabetic.

USING LEFT TRUNCATION AND RIGHT CENSORING

(a) Since the diabetics needed to survive long enough from birth until the study began, the data is left truncated. Construct a table showing the number of subjects at risk, Y, as a function of age.

Left truncated and right censored approach:

a.

	tj	ej	cj	nj	c_tj-1	s_tj
1	0	0	0	21		1
2	60	1	0	5	4/5	0.8
3	62	1	0	9	8/9	0.7111
4	63	1	0	10	9/10	0.64
5	65	2	0	10	8/10	0.512
6	66	1	0	10	9/10	0.4608
7	68	2	0	13	11/13	0.3899
8	69	2	2	14	12/14	0.3342
9	70	2	0	13	11/13	0.2828
10	71	2	0	14	12/14	0.2424
11	72	2	1	14	12/14	0.2078
12	73	1	1	13	12/13	0.1918
13	74	1	1	12	11/12	0.1758
14	76	1	1	11	10/11	0.1598
15	77	1	0	10	9/10	0.1438

where nj is the # at risk Y as a function of age tj. For example at age 62 there are 9 at risk

(b) Estimate the conditional survival function for the age of death of a diabetic patient who has survived to age 60.

Using above table conditional survival for the age of death for a diabetic patient who has survived to age 60 is 0.8

(c) Estimate the conditional survival function for the age of death of a diabetic patient who has survived to age 70.

Using above table conditional survival for the age of death for a diabetic patient who has survived to age 70 is 0.283

(d) Suppose an investigator incorrectly ignored the left truncation and simply treated the data as right censored. Repeat parts a–c.

USING RIGHT CENSORING WHLE IGNORING LEFT CENSORING

(a) Since the diabetics needed to survive long enough from birth until the study began, the data is left truncated. Construct a table showing the number of subjects at risk, Y, as a function of age.

a. Right censored approach while ignoring left truncation:

	orderedEventTimes_tj	eventsAtEventTime_ej	censoredObservationsInInterval_cj	inRiskSetAtTime_nj	kaplanMeirSurvivalCurveAtTime_s_tj-1	c_tj-1	kaplanMeirSurvivalCurveAtTime_s_tj
1	0	0	0	30	-	30/30	1
2	60	1	0	30	1	29/30	0.97
3	62	1	0	29	0.97	28/29	0.94
4	63	1	0	28	0.94	27/28	0.91
5	65	2	0	27	0.91	25/27	0.84
6	66	1	0	25	0.84	24/25	0.81
7	68	2	0	24	0.81	22/24	0.74
8	69	2	2	22	0.74	20/22	0.67
9	70	2	0	18	0.67	16/18	0.6
10	71	2	0	16	0.6	14/16	0.52
11	72	2	1	14	0.52	12/14	0.45
12	73	1	1	11	0.45	10/11	0.41
13	74	1	1	9	0.41	8/9	0.36
14	76	1	1	7	0.36	6/7	0.31
15	77	1	0	5	0.31	4/5	0.25

where inRiskSetAtTIme_nj is the # at risk Y as a function of age tj. For example, at age 63 there are 28 at risk

(b) Estimate the conditional survival function for the age of death of a diabetic patient who has survived to age 60.

Using above table conditional survival for the age of death for a diabetic patient who has survived to age 60 is 0.97

(c) Estimate the conditional survival function for the age of death of a diabetic patient who has survived to age 70.

Using above table conditional survival for the age of death for a diabetic patient who has survived to age 70 is 0.6

R CODE AND OUTPUT BELOW

```
azt_ddc=c("4+",6,11,12,32,35,"38+",39,45,49,75,80,84,85,87,102,"180+")
azt_ddc_saq=c(2,3,4,12,22,48,51,56,80,85,90,94,160,171,180,180,238)

kmTable=data.frame()
getKMTable = function(censoredTimesVector,censorSymbol){
  #get numeric representation of censor vector
  censoredTimesVectorNumeric=as.numeric(sub(censorSymbol,'',censoredTimesVector,fixed=TRUE))
  #count number of actual rows in KM table
  cnt_n=length(censoredTimesVectorNumeric)
  #create first row of KM table
  kmTable=setNames(data.frame(matrix(nrow=1,c(0,0,0,cnt_n,as.character("-"),as.character(paste0(cnt_n,"/",c
nt_n)),1)),stringsAsFactors=FALSE),c("orderedEventTimes_tj","eventsAtEventTime_ej",
  "censoredObservationsInInterval_cj","inRiskSetAtTime_nj","kaplanMeirSurvivalCurveAtTime_s_tj-1","c_tj-1",
"kaplanMeirSurvivalCurveAtTime_s_tj"))
  censoredTimesVectorNumeric=sort(censoredTimesVectorNumeric)
  for (i in 1:max(censoredTimesVectorNumeric)){
    if(i %in% censoredTimesVectorNumeric){
      #create empty row to fill in
      kmTableRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(kmTable)))),names(kmTable))
      kmTableRow$orderedEventTimes_tj=i
      #count how many events at time
      kmTableRow$eventsAtEventTime_ej=length(which(censoredTimesVector==i))
      #count how many censured at time
      kmTableRow$censoredObservationsInInterval_cj=length(which(censoredTimesVector==paste0(i,censorSymbol)
))
      kmTableRow$inRiskSetAtTime_nj=cnt_n
      #sum events and number censored at time
      loss=kmTableRow$eventsAtEventTime_ej+kmTableRow$censoredObservationsInInterval_cj
      prevSurv=kmTable[dim(kmTable)[1],c("kaplanMeirSurvivalCurveAtTime_s_tj")]
      kmTableRow[c("kaplanMeirSurvivalCurveAtTime_s_tj-1")]=prevSurv
      kmTableRow[c("c_tj-1")]=paste0((cnt_n-loss),"/",cnt_n)
      #kmTableRow$kaplanMeirSurvivalCurveAtTime_s_tj=round((cnt_n-loss)/length(censoredTimesVectorNumeric),
3)
```

```
      kmTableRow$kaplanMeirSurvivalCurveAtTime_s_tj=round((cnt_n-loss)/cnt_n*as.numeric(prevSurv),3)
      #update count
      cnt_n=cnt_n-loss
      if(kmTableRow$censoredObservationsInInterval_cj==0){
        #add row to kmtable
        kmTable=rbind(kmTable,kmTableRow)
      }
    }
  }
  kmTable
}
azt_ddc_KM=getKMTable(azt_ddc,"+")
azt_ddc_saq_KM=getKMTable(azt_ddc_saq,"+")
show(azt_ddc_KM)
```

```
##    orderedEventTimes_tj eventsAtEventTime_ej
## 1                     0                    0
## 2                     6                    1
## 3                    11                    1
## 4                    12                    1
## 5                    32                    1
## 6                    35                    1
## 7                    39                    1
## 8                    45                    1
## 9                    49                    1
## 10                   75                    1
## 11                   80                    1
## 12                   84                    1
## 13                   85                    1
## 14                   87                    1
## 15                  102                    1
##    censoredObservationsInInterval_cj inRiskSetAtTime_nj
## 1                                  0                17
## 2                                  0                16
## 3                                  0                15
## 4                                  0                14
```

```
## 5                                    0                 13
## 6                                    0                 12
## 7                                    0                 10
## 8                                    0                  9
## 9                                    0                  8
## 10                                   0                  7
## 11                                   0                  6
## 12                                   0                  5
## 13                                   0                  4
## 14                                   0                  3
## 15                                   0                  2
##    kaplanMeirSurvivalCurveAtTime_s_tj-1 c_tj-1
## 1                                     -  17/17
## 2                                     1  15/16
## 3                                 0.938  14/15
## 4                                 0.875  13/14
## 5                                 0.812  12/13
## 6                                  0.75  11/12
## 7                                 0.688   9/10
## 8                                 0.619    8/9
## 9                                  0.55    7/8
## 10                                0.481    6/7
## 11                                0.412    5/6
## 12                                0.343    4/5
## 13                                0.274    3/4
## 14                                0.206    2/3
## 15                                0.137    1/2
##    kaplanMeirSurvivalCurveAtTime_s_tj
## 1                                   1
## 2                               0.938
## 3                               0.875
## 4                               0.812
## 5                                0.75
## 6                               0.688
## 7                               0.619
## 8                                0.55
```

```
## 9                                0.481
## 10                               0.412
## 11                               0.343
## 12                               0.274
## 13                               0.206
## 14                               0.137
## 15                               0.068
```

```
show(azt_ddc_saq_KM)
```

```
##    orderedEventTimes_tj eventsAtEventTime_ej
## 1                     0                    0
## 2                     2                    1
## 3                     3                    1
## 4                     4                    1
## 5                    12                    1
## 6                    22                    1
## 7                    48                    1
## 8                    51                    1
## 9                    56                    1
## 10                   80                    1
## 11                   85                    1
## 12                   90                    1
## 13                   94                    1
## 14                  160                    1
## 15                  171                    1
## 16                  180                    2
## 17                  238                    1
##    censoredObservationsInInterval_cj inRiskSetAtTime_nj
## 1                                  0                17
## 2                                  0                17
## 3                                  0                16
## 4                                  0                15
## 5                                  0                14
## 6                                  0                13
## 7                                  0                12
```

```
## 8                                    0                 11
## 9                                    0                 10
## 10                                   0                  9
## 11                                   0                  8
## 12                                   0                  7
## 13                                   0                  6
## 14                                   0                  5
## 15                                   0                  4
## 16                                   0                  3
## 17                                   0                  1
##    kaplanMeirSurvivalCurveAtTime_s_tj-1 c_tj-1
## 1                                     -  17/17
## 2                                     1  16/17
## 3                                 0.941  15/16
## 4                                 0.882  14/15
## 5                                 0.823  13/14
## 6                                 0.764  12/13
## 7                                 0.705  11/12
## 8                                 0.646  10/11
## 9                                 0.587   9/10
## 10                                0.528    8/9
## 11                                0.469    7/8
## 12                                 0.41    6/7
## 13                                0.351    5/6
## 14                                0.292    4/5
## 15                                0.234    3/4
## 16                                0.176    1/3
## 17                                0.059    0/1
##    kaplanMeirSurvivalCurveAtTime_s_tj
## 1                                   1
## 2                               0.941
## 3                               0.882
## 4                               0.823
## 5                               0.764
## 6                               0.705
## 7                               0.646
```

```
## 8                                  0.587
## 9                                  0.528
## 10                                 0.469
## 11                                  0.41
## 12                                 0.351
## 13                                 0.292
## 14                                 0.234
## 15                                 0.176
## 16                                 0.059
## 17                                     0
```

```
library(survival)
```

```
## Warning: package 'survival' was built under R version 3.5.2
```

```
#numeric times and censor list (0 for not censored 1 for censored)
Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1))
```

```
##  [1]   4+   6   11   12   32   35   38+  39   45   49   75   80   84   85
## [15]  87  102  180+
```

```
azt_ddc_KM_R=survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0
,1))~1,conf.type="log-log")
summary(azt_ddc_KM_R)
```

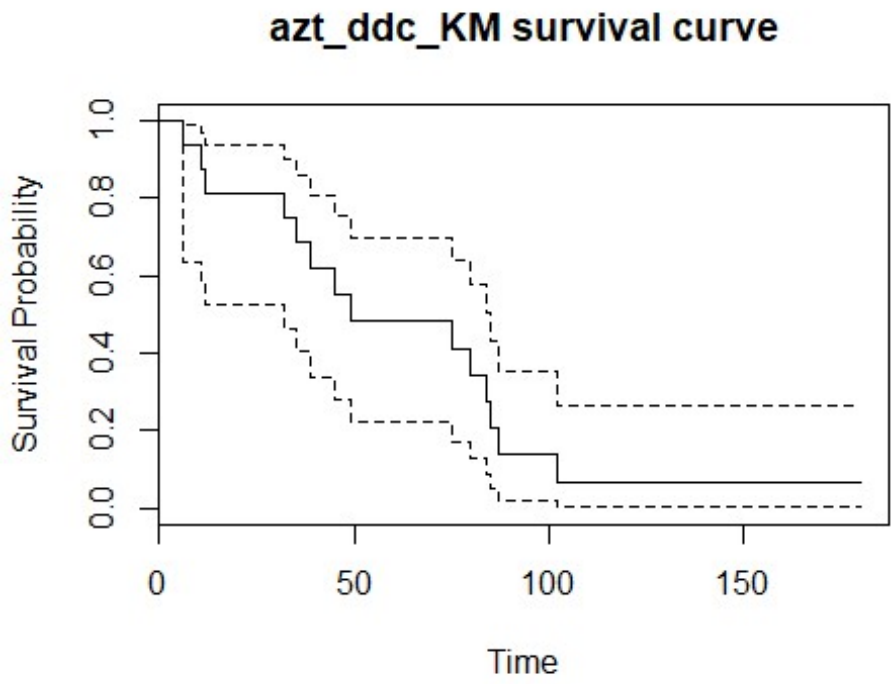
```
## Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc, fixed = TRUE)),
##     ifelse(grepl("+", azt_ddc, fixed = TRUE), 0, 1)) ~ 1, conf.type = "log-log")
##
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     6     16       1   0.9375  0.0605      0.63235        0.991
##    11     15       1   0.8750  0.0827      0.58598        0.967
##    12     14       1   0.8125  0.0976      0.52460        0.935
##    32     13       1   0.7500  0.1083      0.46343        0.898
##    35     12       1   0.6875  0.1159      0.40460        0.856
##    39     10       1   0.6188  0.1230      0.33929        0.808
##    45      9       1   0.5500  0.1271      0.27933        0.756
##    49      8       1   0.4813  0.1285      0.22410        0.699
```

```
##    75      7       1   0.4125  0.1272      0.17339        0.639
##    80      6       1   0.3438  0.1232      0.12728        0.575
##    84      5       1   0.2750  0.1162      0.08617        0.507
##    85      4       1   0.2063  0.1055      0.05082        0.433
##    87      3       1   0.1375  0.0900      0.02265        0.354
##   102      2       1   0.0688  0.0662      0.00443        0.267
```

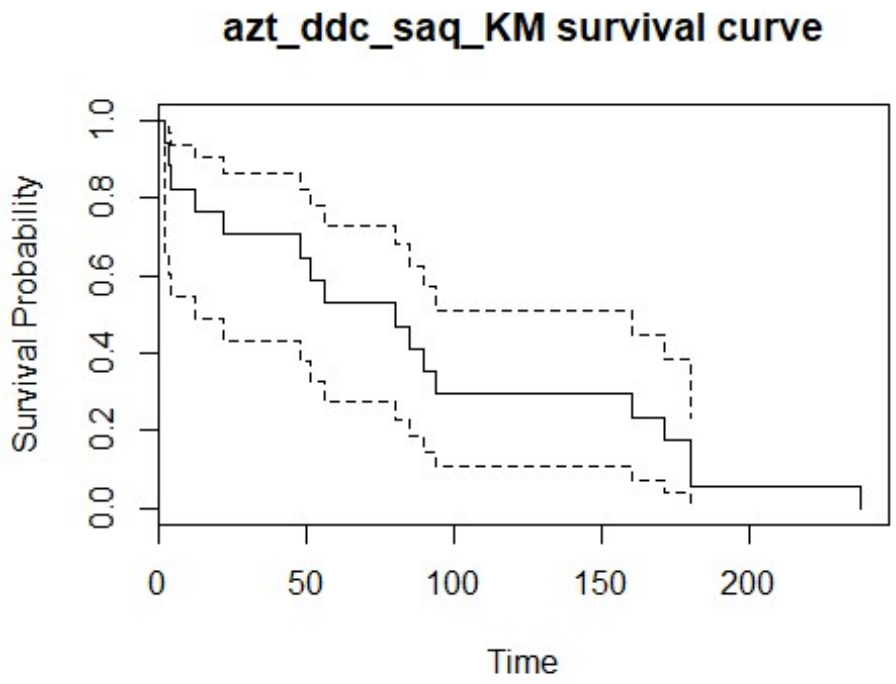
```
azt_ddc_saq_KM_R = survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq
,fixed=TRUE),0,1))~1,conf.type="log-log")
summary(azt_ddc_saq_KM_R)
```

```
## Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc_saq, fixed = TRUE)),
##     ifelse(grepl("+", azt_ddc_saq, fixed = TRUE), 0, 1)) ~ 1,
##     conf.type = "log-log")
##
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     2     17       1   0.9412  0.0571      0.65018        0.991
##     3     16       1   0.8824  0.0781      0.60598        0.969
##     4     15       1   0.8235  0.0925      0.54713        0.939
##    12     14       1   0.7647  0.1029      0.48828        0.904
##    22     13       1   0.7059  0.1105      0.43148        0.866
##    48     12       1   0.6471  0.1159      0.37715        0.823
##    51     11       1   0.5882  0.1194      0.32537        0.778
##    56     10       1   0.5294  0.1211      0.27617        0.730
##    80      9       1   0.4706  0.1211      0.22960        0.680
##    85      8       1   0.4118  0.1194      0.18576        0.626
##    90      7       1   0.3529  0.1159      0.14483        0.570
##    94      6       1   0.2941  0.1105      0.10712        0.511
##   160      5       1   0.2353  0.1029      0.07308        0.449
##   171      4       1   0.1765  0.0925      0.04348        0.383
##   180      3       2   0.0588  0.0571      0.00391        0.235
##   238      1       1   0.0000     NaN           NA           NA
```

```
plot(azt_ddc_KM_R,xlab="Time",ylab="Survival Probability",main="azt_ddc_KM survival curve")
```




```
plot(azt_ddc_saq_KM_R,xlab="Time",ylab="Survival Probability",main="azt_ddc_saq_KM survival curve")
```



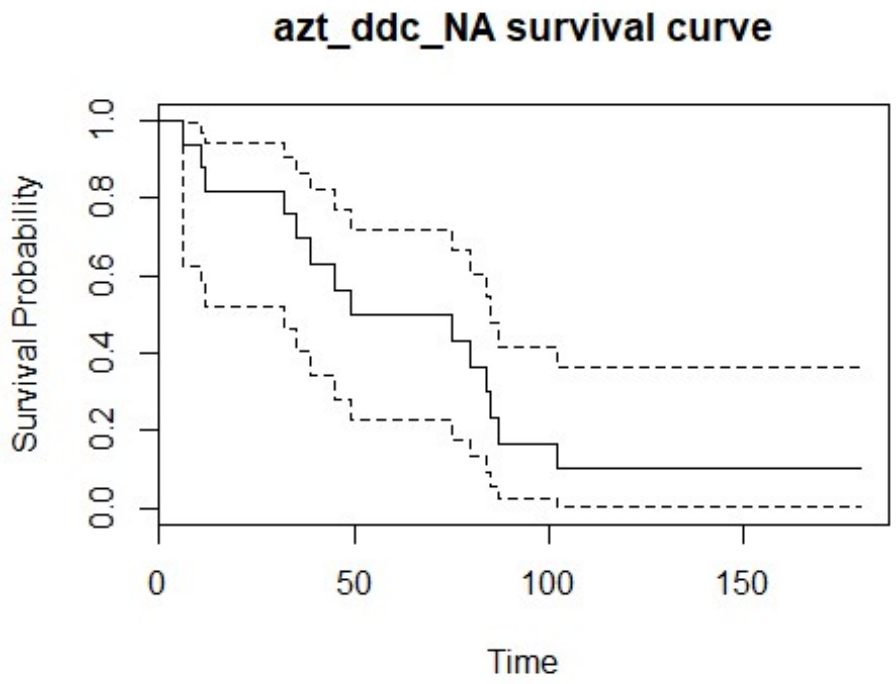
For both groups separately, construct a data layout (similar to what was done in lecture slides) containing the unique, ordered event times, the number of events that occurred at those unique event times, the number of censored observations in the relevant interval, the number in the risk set at that time, and the Kaplan-Meier estimate of the survival curve at that time. What is the median survival time in the two groups? Will you be comfortable reporting the mean survival time in the two groups?

```
#6MP as test case
leukemia_6MP = c(10,7,"32+",23,22,6,16,"34+","32+","25+","11+","20+","19+",6,"17+","35+",6,13,"9+","6+","10
+")
getNATable = function(censoredTimesVector,censorSymbol){
  #get numeric representation of censor vector
```

```r
  censoredTimesVectorNumeric=as.numeric(sub(censorSymbol,'',censoredTimesVector,fixed=TRUE))
  #count number of actual rows in NA table
  cnt_n=length(censoredTimesVectorNumeric)
  #create first row of NA table
  naTable=setNames(data.frame(matrix(nrow=1,c(0,0,cnt_n,0,0,as.character(paste0(cnt_n,"/",cnt_n)),0,0)),str
ingsAsFactors=FALSE),c("orderedEventTimes_tj","eventsAtEventTime_ej","inRiskSetAtTime_nj","censoredObservat
ionsInInterval_cj","cumulativeHazardRate_ht","d_Y_ratio","cumulativeHazardEstimatedVariance_vt","nelsonAale
nSurvivalCurveAtTime_s_tj"))
  censoredTimesVectorNumeric=sort(censoredTimesVectorNumeric)
  sumCensoredInInterval=0
  for (i in 1:max(censoredTimesVectorNumeric)){
    if(i %in% censoredTimesVectorNumeric){
      #create empty row to fill in
      naTableRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(naTable)))),names(naTable))
      naTableRow$orderedEventTimes_tj=i
      #count how many events at time
      naTableRow$eventsAtEventTime_ej=length(which(censoredTimesVector==i))
      #running total of censured between censured time intervals
      naTableRow$censoredObservationsInInterval_cj=length(which(censoredTimesVector==paste0(i,censorSymbol)
))
      sumCensoredInInterval=sumCensoredInInterval+naTableRow$censoredObservationsInInterval_cj
      naTableRow$inRiskSetAtTime_nj=cnt_n
      naTableRow$d_Y_ratio=paste0((naTableRow$eventsAtEventTime_ej),"/",cnt_n)
      naTableRow$cumulativeHazardRate_ht=round(as.numeric(naTable[dim(naTable)[1],c("cumulativeHazardRate_h
t")])+naTableRow$eventsAtEventTime_ej/cnt_n,3)
      naTableRow$cumulativeHazardEstimatedVariance_vt=round(as.numeric(naTable[dim(naTable)[1],c("cumulativ
eHazardEstimatedVariance_vt")])+naTableRow$eventsAtEventTime_ej/(cnt_n)^2,3)
      naTableRow$nelsonAalenSurvivalCurveAtTime_s_tj=round(exp(-naTableRow$cumulativeHazardRate_ht),3)
      #sum events and number censored at time
      loss=naTableRow$eventsAtEventTime_ej+naTableRow$censoredObservationsInInterval_cj
      #update count
      cnt_n=cnt_n-loss
      #add row to na table if at least one uncensored variable
      if (i %in% censoredTimesVector){
        naTableRow$censoredObservationsInInterval_cj=sumCensoredInInterval
        naTable=rbind(naTable,naTableRow)
```

```
        sumCensoredInInterval=0
      }
    }
  }
  naTable
}

#adapted from http://sas-and-r.blogspot.com/2010/05/example-739-nelson-aalen-estimate-of.html
getCumulativeHazardNA = function(time, event) {
   na.fit = survfit(coxph(Surv(time,event)~1), type="aalen")
   jumps = c(0, na.fit$time, max(time))
   # need to be careful at the beginning and end
   surv = c(1, na.fit$surv, na.fit$surv[length(na.fit$surv)])
   # apply appropriate transformation
   neglogsurv = -log(surv)
   # create placeholder of correct length
   naest = numeric(length(time))
   for (i in 2:length(jumps)) {
      naest[which(time>=jumps[i-1] & time<=jumps[i])] =
         neglogsurv[i-1]   # snag the appropriate value
   }
   return(sort(unique(naest)))
}

#TEST SET VALIDATED BY TABLE 4.2 in text page 95
# leukemia_6MP_NA=getNATable(leukemia_6MP,"+")
# leukemia_6MP_NA_R=survfit(Surv(as.numeric(sub("+","",leukemia_6MP,fixed=TRUE)),ifelse(grepl("+",leukemia_
6MP,fixed=TRUE),0,1))~1,conf.type="log-log",type="fh")
# summary(leukemia_6MP_NA_R)
# plot(leukemia_6MP_NA_R,xlab="Time",ylab="Survival Probability",main="leukemia_6MP_NA_R survival curve")
# leukemia_6MP_NA_CH_R=getCumulativeHazardNA(as.numeric(sub("+","",leukemia_6MP,fixed=TRUE)),ifelse(grepl("
+",leukemia_6MP,fixed=TRUE),0,1))

azt_ddc_NA=getNATable(azt_ddc,"+")
azt_ddc_NA_R=survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0
```

```
,1))~1,conf.type="log-log",type="fh")
summary(azt_ddc_NA_R)

## Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc, fixed = TRUE)),
##     ifelse(grepl("+", azt_ddc, fixed = TRUE), 0, 1)) ~ 1, conf.type = "log-log",
##     type = "fh")
##
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     6     16       1    0.939  0.0606      0.62304        0.992
##    11     15       1    0.879  0.0830      0.58170        0.970
##    12     14       1    0.818  0.0983      0.52281        0.940
##    32     13       1    0.758  0.1094      0.46341        0.905
##    35     12       1    0.697  0.1175      0.40600        0.865
##    39     10       1    0.631  0.1254      0.34186        0.820
##    45      9       1    0.564  0.1304      0.28289        0.772
##    49      8       1    0.498  0.1330      0.22843        0.720
##    75      7       1    0.432  0.1331      0.17823        0.664
##    80      6       1    0.366  0.1310      0.13234        0.606
##    84      5       1    0.299  0.1264      0.09106        0.545
##    85      4       1    0.233  0.1192      0.05506        0.481
##    87      3       1    0.167  0.1093      0.02560        0.417
##   102      2       1    0.101  0.0976      0.00539        0.367

plot(azt_ddc_NA_R,xlab="Time",ylab="Survival Probability",main="azt_ddc_NA survival curve")
```




```
#cumulative hazard, confirmation of results
azt_ddc_NA_CH_R=getCumulativeHazardNA(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,f
ixed=TRUE),0,1))
show(azt_ddc_NA)
```

```
##    orderedEventTimes_tj eventsAtEventTime_ej inRiskSetAtTime_nj
## 1                     0                    0                 17
## 2                     6                    1                 16
## 3                    11                    1                 15
## 4                    12                    1                 14
## 5                    32                    1                 13
## 6                    35                    1                 12
## 7                    39                    1                 10
```

```
## 8                     45                     1                    9
## 9                     49                     1                    8
## 10                    75                     1                    7
## 11                    80                     1                    6
## 12                    84                     1                    5
## 13                    85                     1                    4
## 14                    87                     1                    3
## 15                   102                     1                    2
##    censoredObservationsInInterval_cj cumulativeHazardRate_ht d_Y_ratio
## 1                                  0                       0     17/17
## 2                                  1                   0.062      1/16
## 3                                  0                   0.129      1/15
## 4                                  0                     0.2      1/14
## 5                                  0                   0.277      1/13
## 6                                  0                    0.36      1/12
## 7                                  1                    0.46      1/10
## 8                                  0                   0.571       1/9
## 9                                  0                   0.696       1/8
## 10                                 0                   0.839       1/7
## 11                                 0                   1.006       1/6
## 12                                 0                   1.206       1/5
## 13                                 0                   1.456       1/4
## 14                                 0                   1.789       1/3
## 15                                 0                   2.289       1/2
##    cumulativeHazardEstimatedVariance_vt
## 1                                     0
## 2                                 0.004
## 3                                 0.008
## 4                                 0.013
## 5                                 0.019
## 6                                 0.026
## 7                                 0.036
## 8                                 0.048
## 9                                 0.064
## 10                                0.084
## 11                                0.112
```

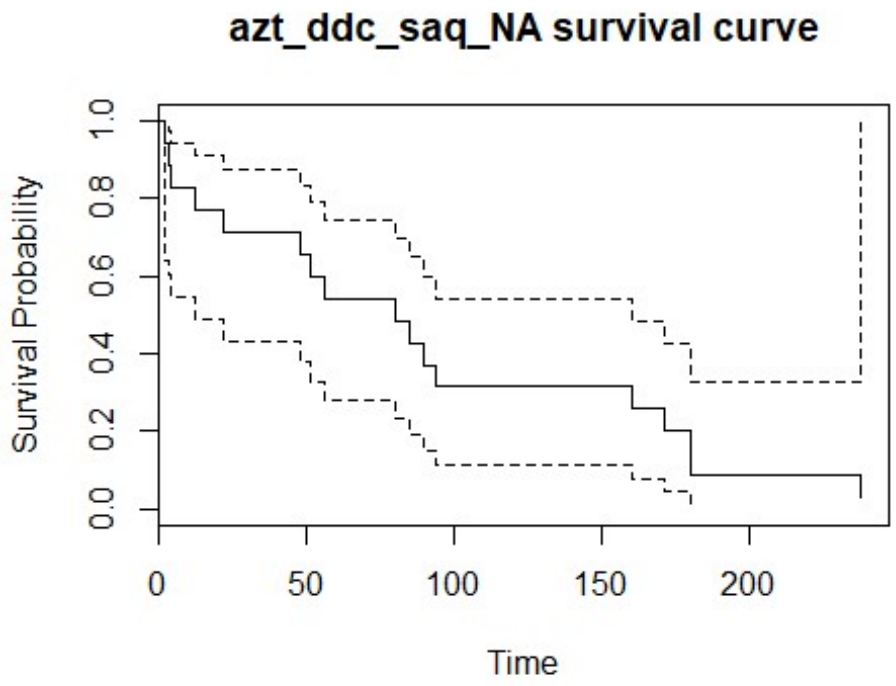
```
## 12                                  0.152
## 13                                  0.214
## 14                                  0.325
## 15                                  0.575
##    nelsonAalenSurvivalCurveAtTime_s_tj
## 1                                    0
## 2                                 0.94
## 3                                0.879
## 4                                0.819
## 5                                0.758
## 6                                0.698
## 7                                0.631
## 8                                0.565
## 9                                0.499
## 10                               0.432
## 11                               0.366
## 12                               0.299
## 13                               0.233
## 14                               0.167
## 15                               0.101
```

```
azt_ddc_saq_NA=getNATable(azt_ddc_saq,"+")
azt_ddc_saq_NA_R = survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq
,fixed=TRUE),0,1))~1,conf.type="log-log",type="fh")
summary(azt_ddc_saq_NA_R)
```

```
## Call: survfit(formula = Surv(as.numeric(sub("+", "", azt_ddc_saq, fixed = TRUE)),
##     ifelse(grepl("+", azt_ddc_saq, fixed = TRUE), 0, 1)) ~ 1,
##     conf.type = "log-log", type = "fh")
##
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     2     17       1   0.9429  0.0572       0.6417        0.992
##     3     16       1   0.8857  0.0784       0.6021        0.971
##     4     15       1   0.8286  0.0930       0.5455        0.943
##    12     14       1   0.7715  0.1038       0.4883        0.910
##    22     13       1   0.7144  0.1118       0.4328        0.874
```

```
##     48      12       1   0.6573  0.1177       0.3795        0.834
##     51      11       1   0.6001  0.1218       0.3287        0.791
##     56      10       1   0.5430  0.1242       0.2802        0.746
##     80       9       1   0.4859  0.1250       0.2343        0.698
##     85       8       1   0.4288  0.1243       0.1908        0.649
##     90       7       1   0.3717  0.1221       0.1501        0.597
##     94       6       1   0.3147  0.1182       0.1124        0.543
##    160       5       1   0.2576  0.1126       0.0780        0.486
##    171       4       1   0.2006  0.1051       0.0476        0.428
##    180       3       2   0.0872  0.0846       0.0049        0.327
##    238       1       1   0.0321     Inf          NaN        1.000
```

```
plot(azt_ddc_saq_NA_R,xlab="Time",ylab="Survival Probability",main="azt_ddc_saq_NA survival curve")
```

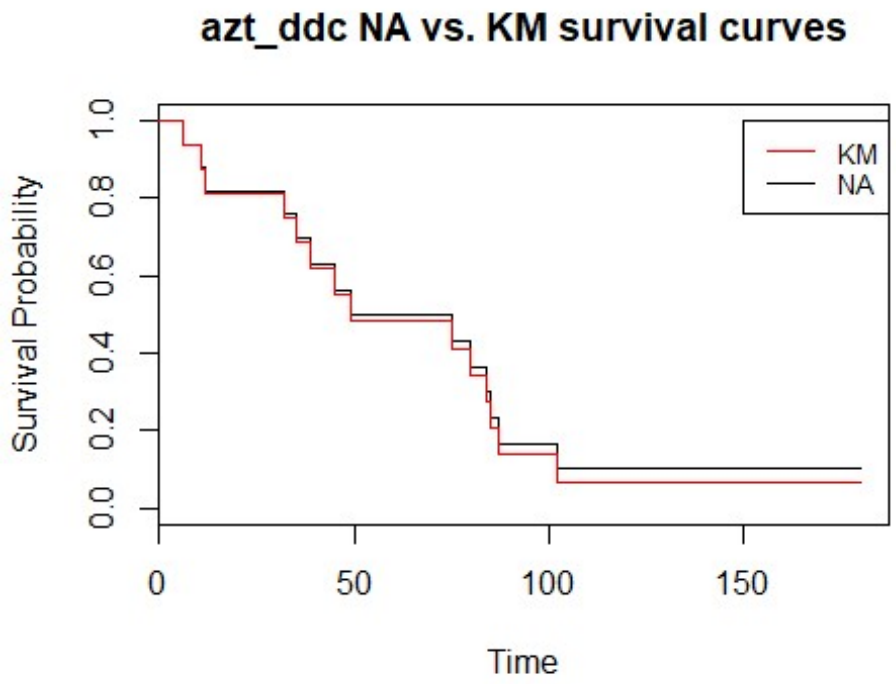


```r
#cumulative hazard, confirmation of results
azt_ddc_saq_NA_CH_R=getCumulativeHazardNA(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",a
zt_ddc_saq,fixed=TRUE),0,1))
show(azt_ddc_saq_NA)
```

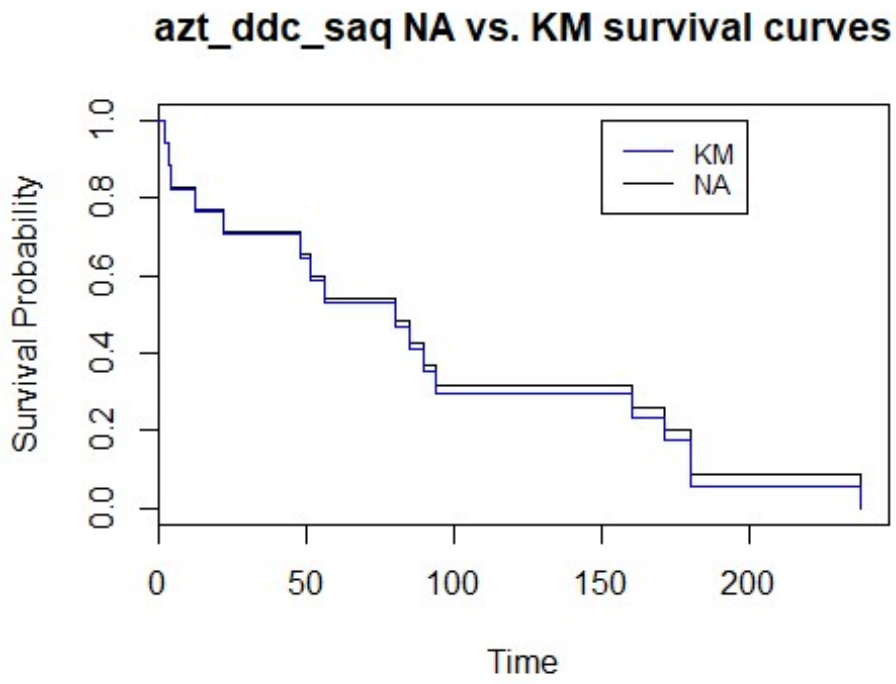
```
##    orderedEventTimes_tj eventsAtEventTime_ej inRiskSetAtTime_nj
## 1                     0                    0                17
## 2                     2                    1                17
## 3                     3                    1                16
## 4                     4                    1                15
## 5                    12                    1                14
## 6                    22                    1                13
## 7                    48                    1                12
## 8                    51                    1                11
## 9                    56                    1                10
## 10                   80                    1                 9
## 11                   85                    1                 8
## 12                   90                    1                 7
## 13                   94                    1                 6
## 14                  160                    1                 5
## 15                  171                    1                 4
## 16                  180                    2                 3
## 17                  238                    1                 1
##    censoredObservationsInInterval_cj cumulativeHazardRate_ht d_Y_ratio
## 1                                  0                      0     17/17
## 2                                  0                  0.059      1/17
## 3                                  0                  0.122      1/16
## 4                                  0                  0.189      1/15
## 5                                  0                   0.26      1/14
## 6                                  0                  0.337      1/13
## 7                                  0                   0.42      1/12
## 8                                  0                  0.511      1/11
## 9                                  0                  0.611      1/10
## 10                                 0                  0.722       1/9
## 11                                 0                  0.847       1/8
## 12                                 0                   0.99       1/7
```

```
## 13                                  0                   1.157       1/6
## 14                                  0                   1.357       1/5
## 15                                  0                   1.607       1/4
## 16                                  0                   2.274       2/3
## 17                                  0                   3.274       1/1
##    cumulativeHazardEstimatedVariance_vt
## 1                                     0
## 2                                 0.003
## 3                                 0.007
## 4                                 0.011
## 5                                 0.016
## 6                                 0.022
## 7                                 0.029
## 8                                 0.037
## 9                                 0.047
## 10                                0.059
## 11                                0.075
## 12                                0.095
## 13                                0.123
## 14                                0.163
## 15                                0.226
## 16                                0.448
## 17                                1.448
##    nelsonAalenSurvivalCurveAtTime_s_tj
## 1                                    0
## 2                                0.943
## 3                                0.885
## 4                                0.828
## 5                                0.771
## 6                                0.714
## 7                                0.657
## 8                                  0.6
## 9                                0.543
## 10                               0.486
## 11                               0.429
## 12                               0.372
```

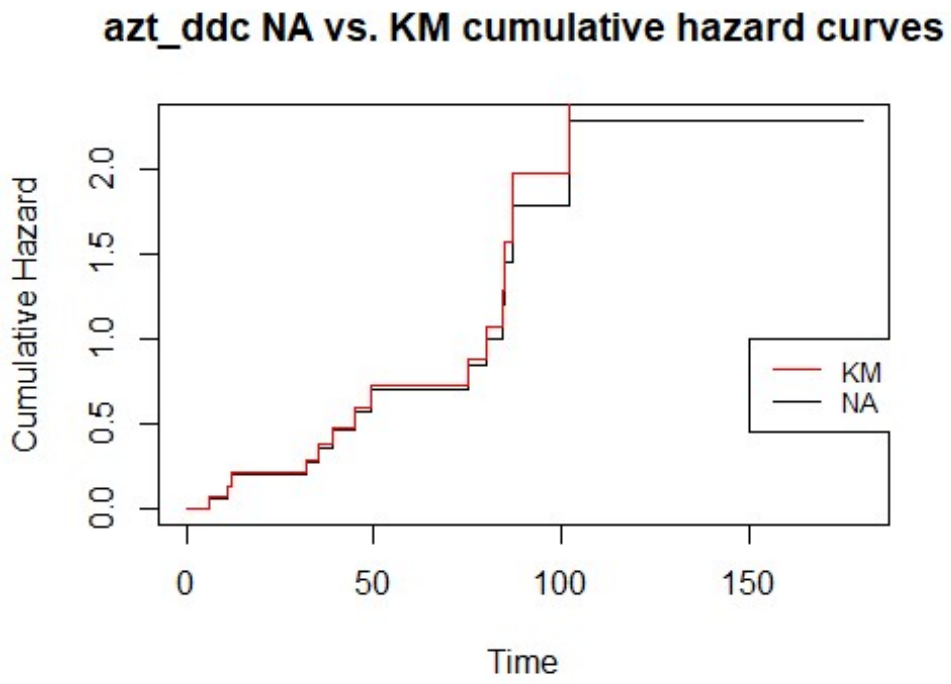
```
## 13                                0.314
## 14                                0.257
## 15                                  0.2
## 16                                0.103
## 17                                0.038

#compare NA to KM survival curve graphically
#azt_ddc
plot(survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1))~1,c
onf.type="none",type="fh"),xlab="Time",ylab="Survival Probability",main="azt_ddc NA vs. KM survival curves"
)
lines(survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1))~1,
conf.type="none",type="kaplan-meier"),col="red")
legend(150, 1, legend=c("KM", "NA"),
       col=c("red", "black"), lty=1,cex=0.8)
```



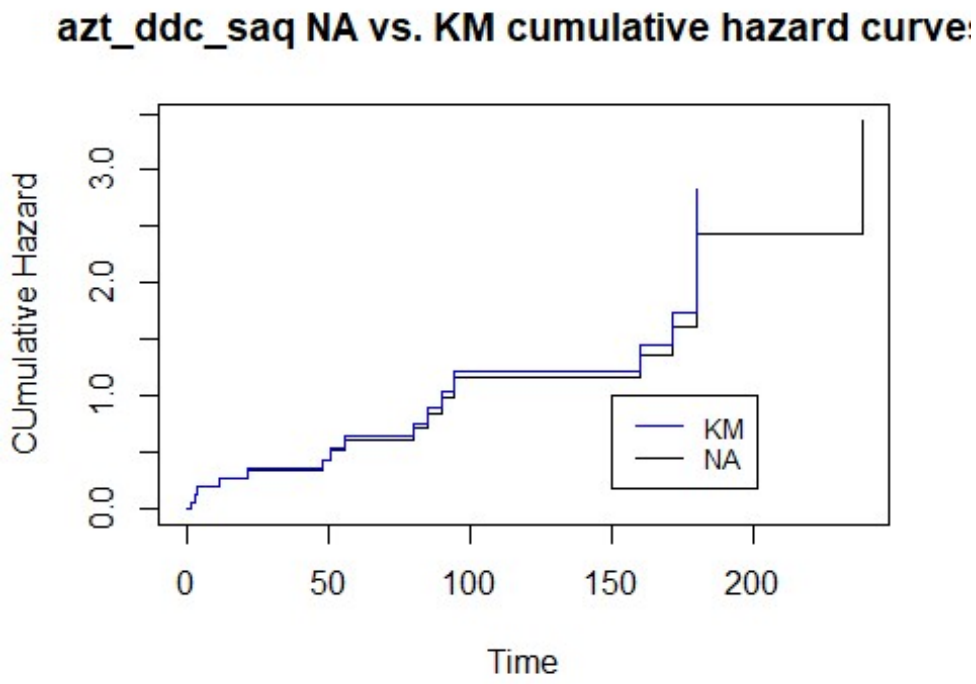

```
#azt_ddc_saq
plot(survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq,fixed=TRUE),0
,1))~1,conf.type="none",type="fh"),xlab="Time",ylab="Survival Probability",main="azt_ddc_saq NA vs. KM surv
ival curves")
lines(survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq,fixed=TRUE),
0,1))~1,conf.type="none",type="kaplan-meier"),col="blue")
legend(150, 1, legend=c("KM", "NA"),
       col=c("blue", "black"), lty=1,cex=0.8)
```




```
#compare NA to KM cumulative hazard curve graphically
plot(survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1))~1,c
onf.type="none",type="fh"),xlab="Time",ylab="Cumulative Hazard",main="azt_ddc NA vs. KM cumulative hazard c
urves",fun="cumhaz")
lines(survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1))~1,
conf.type="none",type="kaplan-meier"),col="red",fun="cumhaz")
legend(150, 1, legend=c("KM", "NA"),
       col=c("red", "black"), lty=1,cex=0.8)
```




```
#azt_ddc_saq
plot(survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq,fixed=TRUE),0
,1))~1,conf.type="none",type="fh"),xlab="Time",ylab="CUmulative Hazard",main="azt_ddc_saq NA vs. KM cumulat
ive hazard curves",fun="cumhaz")
lines(survfit(Surv(as.numeric(sub("+","",azt_ddc_saq,fixed=TRUE)),ifelse(grepl("+",azt_ddc_saq,fixed=TRUE),
0,1))~1,conf.type="none",type="kaplan-meier"),col="blue",fun="cumhaz")
legend(150, 1, legend=c("KM", "NA"),
       col=c("blue", "black"), lty=1,cex=0.8)
```




```
library(KMsurv)

## Warning: package 'KMsurv' was built under R version 3.5.2

library(tidyverse)

## -- Attaching packages ---------------------------------------------------------------------------
------------------------------------ tidyverse 1.2.1 --

## v ggplot2 3.1.0     v purrr   0.2.5
## v tibble  1.4.2     v dplyr   0.7.6
## v tidyr   0.8.1     v stringr 1.3.1
## v readr   1.2.1     v forcats 0.3.0
```

```
## -- Conflicts -------------------------------------------------------------------------------------
------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

getLifeTableInput = function(censoredTimesVector,censorSymbol){
  #get numeric representation of censor vector
  censoredTimesVectorNumeric=as.numeric(sub(censorSymbol,'',censoredTimesVector,fixed=TRUE))
  #count number of actual rows in KM table
  cnt_n=length(censoredTimesVectorNumeric)
  #create first row of KM table
  lifeTableInputTable=setNames(data.frame(matrix(nrow=1,c(NA,NA,NA)),stringsAsFactors=FALSE),c("time","nlos
t","nevent"))
  censoredTimesVectorNumeric=sort(censoredTimesVectorNumeric)
  for (i in 1:max(censoredTimesVectorNumeric)){
    if(i %in% censoredTimesVectorNumeric){
      #create empty row to fill in
      lifeTableInputRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(lifeTableInputTable)))),name
s(lifeTableInputTable))
      lifeTableInputRow$time=i
      #count how many events at time
      lifeTableInputRow$nevent=length(which(censoredTimesVector==i))
      #count how many censured at time
      lifeTableInputRow$nlost=length(which(censoredTimesVector==paste0(i,censorSymbol)))
      lifeTableInputTable=rbind(lifeTableInputTable,lifeTableInputRow)
    }
  }
  na.omit(lifeTableInputTable)
}
azt_ddc_numeric=as.numeric(gsub("+","",azt_ddc,fixed=TRUE))
cuts_ad=seq(0,max(azt_ddc_numeric),60)
#ensure no loss of upper bound when incrementing
if(max(azt_ddc_numeric)>cuts_ad[length(cuts_ad)]){cuts_ad=cuts_ad=c(cuts_ad,(max(azt_ddc_numeric)))}
azt_ddc_lt_raw=getLifeTableInput(azt_ddc,"+")
lifetab_dat=mutate(azt_ddc_lt_raw,time_cat = cut(time, cuts_ad)) %>% group_by(time_cat) %>% summarize(ilost
=sum(nlost),ievent=sum(nevent))
```

```r
azt_ddc_lt=lifetab(tis = c(0,azt_ddc_lt_raw$time), ninit = length(azt_ddc), nlost = azt_ddc_lt_raw$nlost, n
event = azt_ddc_lt_raw$nevent) %>% drop_na(hazard)
show(azt_ddc_lt)
```

```
##        nsubs nlost nrisk nevent    surv         pdf     hazard    se.surv
## 0-4       17     1  16.5      0 1.00000 0.000000000 0.00000000 0.00000000
## 4-6       16     0  16.0      1 1.00000 0.031250000 0.03225806 0.00000000
## 6-11      15     0  15.0      1 0.93750 0.012500000 0.01379310 0.06051536
## 11-12     14     0  14.0      1 0.87500 0.062500000 0.07407407 0.08267973
## 12-32     13     0  13.0      1 0.81250 0.003125000 0.00400000 0.09757809
## 32-35     12     0  12.0      1 0.75000 0.020833333 0.02898551 0.10825318
## 35-38     11     1  10.5      0 0.68750 0.000000000 0.00000000 0.11587810
## 38-39     10     0  10.0      1 0.68750 0.068750000 0.10526316 0.11587810
## 39-45      9     0   9.0      1 0.61875 0.011458333 0.01960784 0.12300557
## 45-49      8     0   8.0      1 0.55000 0.017187500 0.03333333 0.12710724
## 49-75      7     0   7.0      1 0.48125 0.002644231 0.00591716 0.12847323
## 75-80      6     0   6.0      1 0.41250 0.013750000 0.03636364 0.12719172
## 80-84      5     0   5.0      1 0.34375 0.017187500 0.05555556 0.12318011
## 84-85      4     0   4.0      1 0.27500 0.068750000 0.28571429 0.11615588
## 85-87      3     0   3.0      1 0.20625 0.034375000 0.20000000 0.10551909
## 87-102     2     0   2.0      1 0.13750 0.004583333 0.04444444 0.08999783
##             se.pdf   se.hazard
## 0-4            NaN         NaN
## 4-6    0.030257682 0.032241277
## 6-11   0.012103073 0.013784901
## 11-12  0.060515365 0.074023251
## 12-32  0.003025768 0.003996799
## 32-35  0.020171788 0.028958098
## 35-38          NaN         NaN
## 38-39  0.066243366 0.105117263
## 39-45  0.011040561 0.019573890
## 45-49  0.016560842 0.033259177
## 49-75  0.002547822 0.005899627
## 75-80  0.013248673 0.036213062
## 80-84  0.016560842 0.055211555
## 84-85  0.066243366 0.282783805
```

```
## 85-87  0.033121683 0.195959179
## 87-102 0.004416224 0.041902624
```

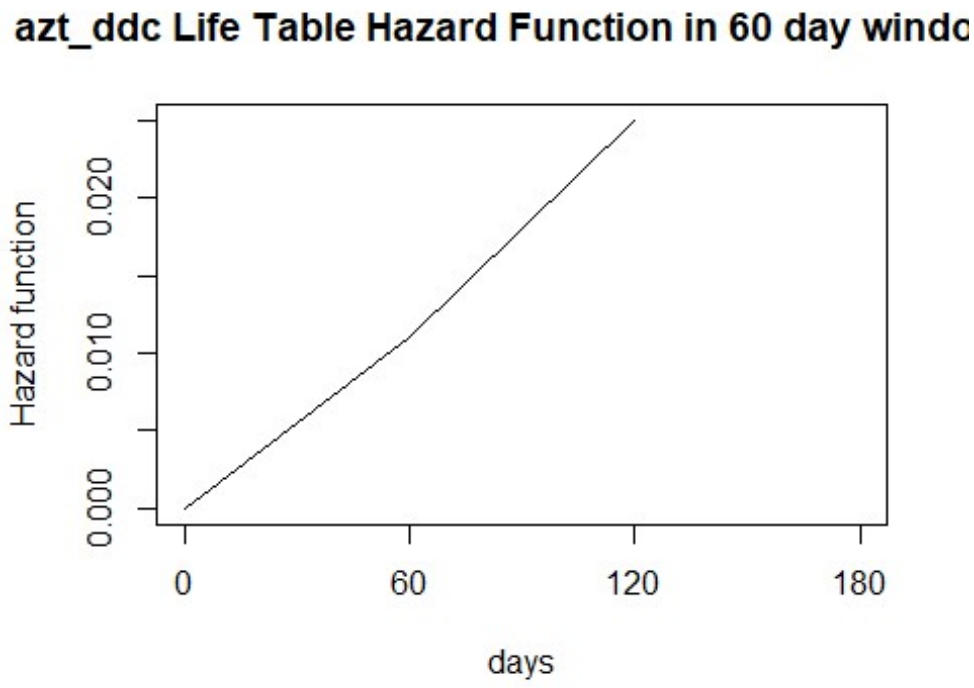
```
azt_ddc_lt_60=lifetab(tis = cuts_ad, ninit = length(azt_ddc), nlost = lifetab_dat$ilost, nevent = lifetab_d
at$ievent)
azt_ddc_saq_numeric=as.numeric(gsub("+","",azt_ddc_saq,fixed=TRUE))
cuts_ads=seq(0,max(azt_ddc_saq_numeric),by=60)
#ensure no loss of upper bound when incrementing
if(max(azt_ddc_saq_numeric)>cuts_ads[length(cuts_ads)]){cuts_ads=c(cuts_ads,(max(azt_ddc_saq_numeric)))}
azt_ddc_saq_lt_raw=getLifeTableInput(azt_ddc_saq,"+")
lifetab_dat=mutate(azt_ddc_saq_lt_raw,time_cat = cut(time, cuts_ads)) %>% group_by(time_cat) %>% summarize(
ilost=sum(nlost),ievent=sum(nevent))
```

```
azt_ddc_saq_lt=lifetab(tis = c(0,azt_ddc_saq_lt_raw$time), ninit = length(azt_ddc_saq), nlost = azt_ddc_saq
_lt_raw$nlost, nevent = azt_ddc_saq_lt_raw$nevent) %>% drop_na(hazard)
show(azt_ddc_saq_lt)
```

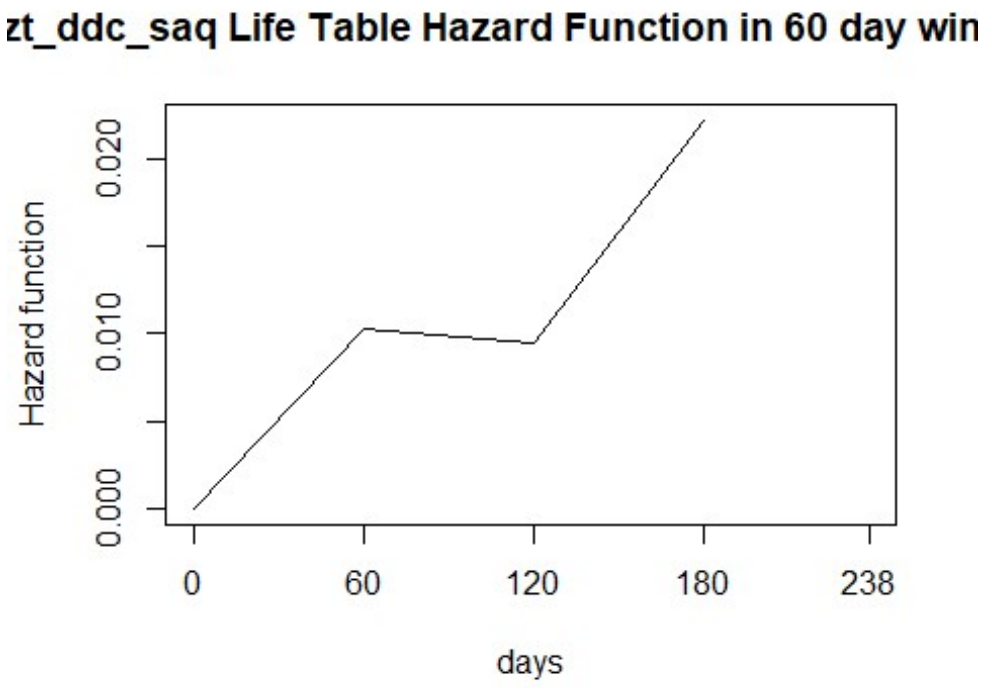
```
##         nsubs nlost nrisk nevent      surv          pdf      hazard
## 0-2        17     0    17      1 1.0000000 0.0294117647 0.030303030
## 2-3        16     0    16      1 0.9411765 0.0588235294 0.064516129
## 3-4        15     0    15      1 0.8823529 0.0588235294 0.068965517
## 4-12       14     0    14      1 0.8235294 0.0073529412 0.009259259
## 12-22      13     0    13      1 0.7647059 0.0058823529 0.008000000
## 22-48      12     0    12      1 0.7058824 0.0022624434 0.003344482
## 48-51      11     0    11      1 0.6470588 0.0196078431 0.031746032
## 51-56      10     0    10      1 0.5882353 0.0117647059 0.021052632
## 56-80       9     0     9      1 0.5294118 0.0024509804 0.004901961
## 80-85       8     0     8      1 0.4705882 0.0117647059 0.026666667
## 85-90       7     0     7      1 0.4117647 0.0117647059 0.030769231
## 90-94       6     0     6      1 0.3529412 0.0147058824 0.045454545
## 94-160      5     0     5      1 0.2941176 0.0008912656 0.003367003
## 160-171     4     0     4      1 0.2352941 0.0053475936 0.025974026
## 171-180     3     0     3      2 0.1764706 0.0130718954 0.111111111
##            se.surv       se.pdf   se.hazard
## 0-2     0.00000000 0.0285336029 0.030289114
## 2-3     0.05706721 0.0570672059 0.064482553
```

```
## 3-4     0.07814249 0.0570672059 0.068924503
## 4-12    0.09245944 0.0071334007 0.009252906
## 12-22   0.10287937 0.0057067206 0.007993597
## 22-48   0.11051017 0.0021948925 0.003341319
## 48-51   0.11590404 0.0190224020 0.031710018
## 51-56   0.11936462 0.0114134412 0.021023453
## 56-80   0.12105782 0.0023778002 0.004893473
## 80-85   0.12105782 0.0114134412 0.026607341
## 85-90   0.11936462 0.0114134412 0.030678062
## 90-94   0.11590404 0.0142668015 0.045266327
## 94-160  0.11051017 0.0008646546 0.003346155
## 160-171 0.10287937 0.0051879278 0.025707619
## 171-180 0.09245944 0.0086824989 0.068041382
```

```
azt_ddc_saq_lt_60=lifetab(tis = cuts_ads, ninit = length(azt_ddc_saq), nlost = lifetab_dat$ilost, nevent =
lifetab_dat$ievent)

#plot azt_ddc
plot(cuts_ad,c(0,azt_ddc_lt_60$hazard),type='l',ylab="Hazard function",xlab="days",xaxt="n",main="azt_ddc L
ife Table Hazard Function in 60 day windows")
axis(1, at = cuts_ad, las=1)
```

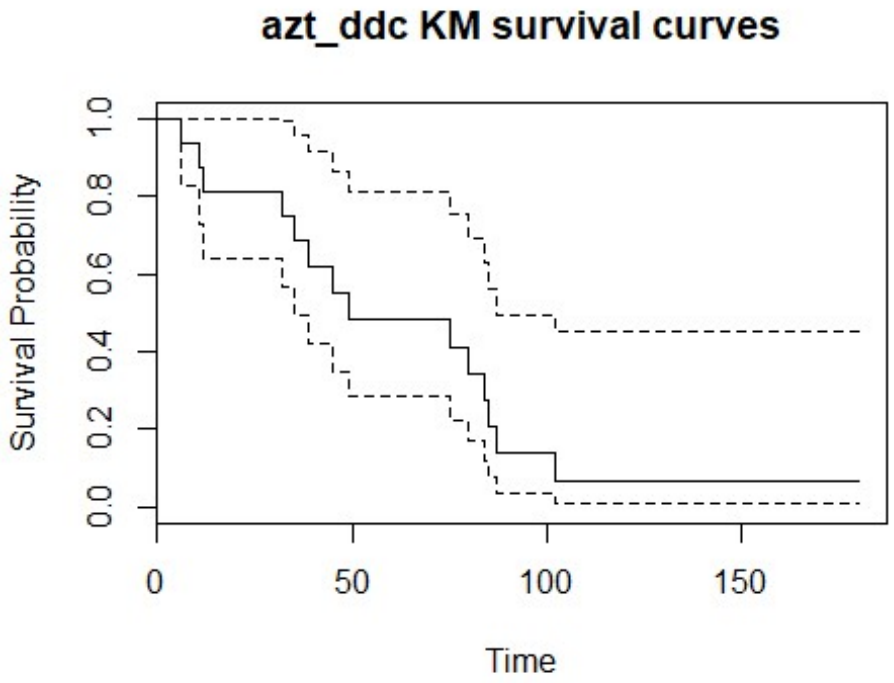



```
#plot azt_ddc_saq
plot(cuts_ads,c(0,azt_ddc_saq_lt_60$hazard),type='l',ylab="Hazard function",xlab="days",xaxt="n",main="azt_
ddc_saq Life Table Hazard Function in 60 day windows")
axis(1, at = cuts_ads, las=1)
```




```
library(kmconfband)

## Warning: package 'kmconfband' was built under R version 3.5.2

#survival function confidence intervals for azt_ddc
azt_ddc_s=survfit(Surv(as.numeric(sub("+","",azt_ddc,fixed=TRUE)),ifelse(grepl("+",azt_ddc,fixed=TRUE),0,1)
)~1)
azt_ddc_s_ci=summary(azt_ddc_s)
azt_ddc_s_ci_df=data.frame(azt_ddc_s_ci$time,azt_ddc_s_ci$n.risk,azt_ddc_s_ci$n.event,azt_ddc_s_ci$surv,azt
_ddc_s_ci$std.err,azt_ddc_s_ci$lower,azt_ddc_s_ci$upper)
#lower and upper intervals and bounds
azt_ddc_s_ci_cb=setNames(cbind(azt_ddc_s_ci_df,confband(azt_ddc_s)[1:dim(azt_ddc_s_ci_df)[1],]),c("time","n
.risk","n.event","survival","std.err","lower 95% CI" ,"upper 95% CI","lower 95% CB" ,"upper 95% CB"))
```

```
## The critical value required is  0.4404776

plot(azt_ddc_s,xlab="Time",ylab="Survival Probability",main="azt_ddc KM survival curves")
```




```
rtr_example=c(3,4,"5+",6,"6+","8+",11,14,15,"16+")
decrement=0
#redistribute to right value
getRedistributeToRightTable = function(censoredTimesVector,censorSymbol){
  #get numeric representation of censor vector
  censoredTimesVectorNumeric=as.numeric(sub(censorSymbol,'',censoredTimesVector,fixed=TRUE))
  #sort to ensure when determine step# omit correct last element
  censoredTimesVector=censoredTimesVector[order(censoredTimesVectorNumeric)]
  #count number of actual rows in RTR table
```

```
  cnt_n=length(censoredTimesVectorNumeric)
  steps=length(which(grepl(censorSymbol,censoredTimesVector[1:length(censoredTimesVector)-1],fixed=TRUE)))
  #create first row of RTR table
  rtrTable=setNames(data.frame(matrix(nrow=1,c(0,(1/cnt_n),"",1)),stringsAsFactors=FALSE),c("observation","
decrement","action","S_t"))
  censoredTimesVectorNumeric=sort(censoredTimesVectorNumeric)
  decrement = 0
  base=1/cnt_n
  i=0
  uniqueCensoredTimesVector=unique(censoredTimesVector)
  for (dataPoint in uniqueCensoredTimesVector){
    i=i+1
    #create empty row to fill in
    rtrTableRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(rtrTable)))),names(rtrTable))
    rtrTableRow$observation=dataPoint
    #count how many events or censures at unique dataPoint
    numerator=length(which(censoredTimesVector==dataPoint))
    #censured at time?
    if(length(which(censoredTimesVector==dataPoint & grep(censorSymbol,dataPoint,fixed=TRUE)))>0){
      #no change in survival function
      rtrTableRow$S_t=rtrTable[dim(rtrTable)[1],c("S_t")]
      #display decrement of 0
      rtrTableRow$decrement=0
      #update denominator
      denominator=length(censoredTimesVector)-max(which(dataPoint == censoredTimesVector))
      if(i==length(uniqueCensoredTimesVector)){
        rtrTableRow$action=paste0("survival is 1-(1)")
        rtrTableRow$S_t=0
        rtrTableRow$decrement=1
      }
      else{
        rtrTableRow$action=paste0("next time survival is 1-(",decrement," + ",base," + ",base,"*",numerator
,"/",denominator,")")
      }
      if(length(uniqueCensoredTimesVector)>=(i+1) && (!grepl(censorSymbol,uniqueCensoredTimesVector[i+1],fi
xed=TRUE))){
```

```
        #update decrement only if not proceeded by a censored observation
        decrement = decrement + base+(base*numerator/denominator)
      }
      #update base
      base=base+(base*numerator/denominator)
    }
    else{
        #update decrement and show action
        if (as.numeric(rtrTable[dim(rtrTable)[1],c("decrement")])==0)
        {
          rtrTableRow$action=paste0("survival is 1-(",decrement,")")
          decrement = decrement
        }
        else{
          decrement = decrement + base
          rtrTableRow$action=paste0("survival is 1-(",decrement,")")
        }
        rtrTableRow$S_t=1-decrement
        #update decrement display
        rtrTableRow$decrement=decrement
    }
      #add row to rtrtable
      rtrTable=rbind(rtrTable,rtrTableRow)
  }
  #eleminate initial bogus row
  rtrTable$decrement=round(as.numeric(rtrTable$decrement),3)
  rtrTable$S_t=round(as.numeric(rtrTable$S_t),3)
  rtrTable[-1,]
}

azt_ddc_saq_RTR=getRedistributeToRightTable(azt_ddc_saq,"+")
azt_ddc_RTR=getRedistributeToRightTable(azt_ddc,"+")
show(azt_ddc_saq_RTR)
```

```
##    observation decrement                              action   S_t
## 2            2     0.059 survival is 1-(0.0588235294117647) 0.941
```

```
## 3            3     0.118  survival is 1-(0.117647058823529) 0.882
## 4            4     0.176  survival is 1-(0.176470588235294) 0.824
## 5           12     0.235  survival is 1-(0.235294117647059) 0.765
## 6           22     0.294  survival is 1-(0.294117647058824) 0.706
## 7           48     0.353  survival is 1-(0.352941176470588) 0.647
## 8           51     0.412  survival is 1-(0.411764705882353) 0.588
## 9           56     0.471  survival is 1-(0.470588235294118) 0.529
## 10          80     0.529  survival is 1-(0.529411764705882) 0.471
## 11          85     0.588  survival is 1-(0.588235294117647) 0.412
## 12          90     0.647  survival is 1-(0.647058823529412) 0.353
## 13          94     0.706  survival is 1-(0.705882352941177) 0.294
## 14         160     0.765  survival is 1-(0.764705882352941) 0.235
## 15         171     0.824  survival is 1-(0.823529411764706) 0.176
## 16         180     0.882  survival is 1-(0.882352941176471) 0.118
## 17         238     0.941  survival is 1-(0.941176470588235) 0.059
```

```
show(azt_ddc_RTR)
```

```
##    observation decrement
## 2           4+     0.000
## 3            6     0.062
## 4           11     0.125
## 5           12     0.188
## 6           32     0.250
## 7           35     0.312
## 8          38+     0.000
## 9           39     0.381
## 10          45     0.450
## 11          49     0.519
## 12          75     0.588
## 13          80     0.656
## 14          84     0.725
## 15          85     0.794
## 16          87     0.862
## 17         102     0.931
## 18        180+     1.000
```

```
##                                                                                 action
## 2  next time survival is 1-(0 + 0.0588235294117647 + 0.0588235294117647*1/16)
## 3                                                                  survival is 1-(0.0625)
## 4                                                                   survival is 1-(0.125)
## 5                                                                  survival is 1-(0.1875)
## 6                                                                    survival is 1-(0.25)
## 7                                                                  survival is 1-(0.3125)
## 8                        next time survival is 1-(0.3125 + 0.0625 + 0.0625*1/10)
## 9                                                                 survival is 1-(0.38125)
## 10                                                                   survival is 1-(0.45)
## 11                                                                survival is 1-(0.51875)
## 12                                                                 survival is 1-(0.5875)
## 13                                                                survival is 1-(0.65625)
## 14                                                                   survival is 1-(0.725)
## 15                                                                survival is 1-(0.79375)
## 16                                                                 survival is 1-(0.8625)
## 17                                                                survival is 1-(0.93125)
## 18                                                                       survival is 1-(1)
##      S_t
## 2  1.000
## 3  0.938
## 4  0.875
## 5  0.812
## 6  0.750
## 7  0.688
## 8  0.688
## 9  0.619
## 10 0.550
## 11 0.481
## 12 0.412
## 13 0.344
## 14 0.275
## 15 0.206
## 16 0.138
## 17 0.069
## 18 0.000
```

```r
rtr_example_RTR = getRedistributeToRightTable(rtr_example,"+")

#column1 of book page 137 problem 4.7
entry_c1 = c(58,58,59,60,60,61,61,62,62,62,63,63,64,66,66)
exit_c1=c(60,63,69,62,65,72,69,73,66,65,68,74,71,68,69)
death_c1 = c(1,1,0,1,1,0,0,0,1,1,1,0,1,1,1)
#column1 of book page 137 problem 4.7
entry_c2=c(67,67,67,68,69,69,69,70,70,70,71,72,72,73,73)
exit_c2=c(70,77,69,72,79,72,70,76,71,78,79,76,73,80,74)
death_c2=c(1,1,1,1,0,1,1,0,1,0,0,1,1,0,1)
df2_lec = data.frame(cbind(entry_c1,exit_c1,death_c1))
df2_prob = setNames(data.frame(cbind(c(entry_c1,entry_c2),c(exit_c1,exit_c2),c(death_c1,death_c2))),c("entr
y","exit","death"))

df2_lec_censored_noLT=c(60,63,"69+",62,65,"72+","69+","73+",66,65,68,"74+",71,68,69)
df2_prob_censored_noLT=c(60,63,"69+",62,65,"72+","69+","73+",66,65,68,"74+",71,68,69,70,77,69,72,"79+",72,7
0,"76+",71,"78+","79+",76,73,"80+",74)

getKM_LT_Table = function(entryExitDeathVector,deathSymbol){
  #create first row of KM_LT table
  km_ltTable=setNames(data.frame(matrix(nrow=1,c(0,0,0,length(entryExitDeathVector),"",1)),stringsAsFactors
=FALSE),c("tj","ej","cj","nj","c_tj-1","s_tj"))
  #sort by exit
  orderedIndices=order(entryExitDeathVector$exit)
  entryExitDeathVector=entryExitDeathVector[orderedIndices,]
  for (time in unique(entryExitDeathVector$exit)){
    total_at_risk=length(which(entryExitDeathVector$entry<=time))
    gone=length(which(entryExitDeathVector$exit<time & entryExitDeathVector$death==deathSymbol))
    events=length(which(entryExitDeathVector$exit==time & entryExitDeathVector$death==deathSymbol))
    truncated_at_risk=total_at_risk-gone-as.numeric(km_ltTable$cj[length(km_ltTable$cj)])
    censored=length(which(entryExitDeathVector$exit==time & entryExitDeathVector$death!=deathSymbol))
    numerator=truncated_at_risk-events
    denominator=truncated_at_risk
    #print(paste0(time,": ",numerator,"/",denominator))
    #create empty row to fill in
    km_ltTableRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(km_ltTable)))),names(km_ltTable))
```

```
    km_ltTableRow$tj=time
    #count how many events at time
    km_ltTableRow$ej=events
    #count how many censured at time
    km_ltTableRow$cj=censored
    km_ltTableRow$nj=truncated_at_risk
    #sum events and number censored at time
    km_ltTableRow[c("c_tj-1")]=paste0(numerator,"/",denominator)
    km_ltTableRow$s_tj=round((numerator/denominator)*as.numeric(km_ltTable[dim(km_ltTable)[1],c("s_tj")]),4
)
    if (km_ltTableRow$ej>0 | km_ltTableRow$s_tj==1){
      #add row to km_lttable
      km_ltTable=rbind(km_ltTable,km_ltTableRow)
    }
  }
  km_ltTable
}
df2_lec_LT=getKM_LT_Table(df2_lec,1)
show(df2_lec_LT)
```

```
##   tj ej cj nj c_tj-1   s_tj
## 1  0  0  0  3            1
## 2 60  1  0  5    4/5    0.8
## 3 62  1  0  9    8/9 0.7111
## 4 63  1  0 10   9/10   0.64
## 5 65  2  0 10   8/10  0.512
## 6 66  1  0 10   9/10 0.4608
## 7 68  2  0  9    7/9 0.3584
## 8 69  1  2  7    6/7 0.3072
## 9 71  1  0  4    3/4 0.2304
```

```
getKMTableNoCensorRemoval = function(censoredTimesVector,censorSymbol){
  #get numeric representation of censor vector
  censoredTimesVectorNumeric=as.numeric(sub(censorSymbol,'',censoredTimesVector,fixed=TRUE))
  #count number of actual rows in KM table
  cnt_n=length(censoredTimesVectorNumeric)
```

```
  #create first row of KM table
  kmTable=setNames(data.frame(matrix(nrow=1,c(0,0,0,cnt_n,as.character("-"),as.character(paste0(cnt_n,"/",c
nt_n)),1)),stringsAsFactors=FALSE),c("orderedEventTimes_tj","eventsAtEventTime_ej",
  "censoredObservationsInInterval_cj","inRiskSetAtTime_nj","kaplanMeirSurvivalCurveAtTime_s_tj-1","c_tj-1",
"kaplanMeirSurvivalCurveAtTime_s_tj"))
  # orderedIndices=order(censoredTimesVectorNumeric)
  # censoredTimesVectorNumeric=censoredTimesVectorNumeric[orderedIndices]
  # censoredTimesVector=censoredTimesVector[orderedIndices]
  censoredTimesVectorNumeric=sort(censoredTimesVectorNumeric)
  for (i in 1:max(censoredTimesVectorNumeric)){
    if(i %in% censoredTimesVectorNumeric){
      #create empty row to fill in
      kmTableRow=setNames(data.frame(matrix(NA,nrow=1,ncol=length(names(kmTable)))),names(kmTable))
      kmTableRow$orderedEventTimes_tj=i
      #count how many events at time
      kmTableRow$eventsAtEventTime_ej=length(which(censoredTimesVector==i))
      #count how many censured at time
      kmTableRow$censoredObservationsInInterval_cj=length(which(censoredTimesVector==paste0(i,censorSymbol)
))
      kmTableRow$inRiskSetAtTime_nj=cnt_n
      #sum events and censored
      loss=kmTableRow$eventsAtEventTime_ej+kmTableRow$censoredObservationsInInterval_cj
      kmTableRow[c("kaplanMeirSurvivalCurveAtTime_s_tj-1")]=kmTable[dim(kmTable)[1],c("kaplanMeirSurvivalCu
rveAtTime_s_tj")]
      #TOOK LAZY WAY OUT AND JUST ADDED BACK IN THE CENSORED OBS - WILL DO CORRECT WAY LATER I Hope
      numerator=(cnt_n-loss+kmTableRow$censoredObservationsInInterval_cj)
      denominator=cnt_n
      kmTableRow[c("c_tj-1")]=paste0(numerator,"/",denominator)
      kmTableRow$kaplanMeirSurvivalCurveAtTime_s_tj=round(numerator/denominator*as.numeric(kmTable[dim(kmTa
ble)[1],c("kaplanMeirSurvivalCurveAtTime_s_tj")]),2)
      #update count
      cnt_n=cnt_n-loss
      #don't add a row when no events 0 should put this at top but no time :0
      if (kmTableRow$eventsAtEventTime_ej>0 | cnt_n==length(censoredTimesVectorNumeric)){
        #add row to kmtable
        kmTable=rbind(kmTable,kmTableRow)
```

```
      }
    }
  }
  kmTable
}
df2_lec_censored_noLT_KM=getKMTableNoCensorRemoval(df2_lec_censored_noLT,"+")
show(df2_lec_censored_noLT_KM)

##   orderedEventTimes_tj eventsAtEventTime_ej
## 1                    0                    0
## 2                   60                    1
## 3                   62                    1
## 4                   63                    1
## 5                   65                    2
## 6                   66                    1
## 7                   68                    2
## 8                   69                    1
## 9                   71                    1
##   censoredObservationsInInterval_cj inRiskSetAtTime_nj
## 1                                 0                15
## 2                                 0                15
## 3                                 0                14
## 4                                 0                13
## 5                                 0                12
## 6                                 0                10
## 7                                 0                 9
## 8                                 2                 7
## 9                                 0                 4
##   kaplanMeirSurvivalCurveAtTime_s_tj-1 c_tj-1
## 1                                    -  15/15
## 2                                    1  14/15
## 3                                 0.93  13/14
## 4                                 0.86  12/13
## 5                                 0.79  10/12
## 6                                 0.66   9/10
## 7                                 0.59    7/9
```

```
## 8                                  0.46    6/7
## 9                                  0.39    3/4
##   kaplanMeirSurvivalCurveAtTime_s_tj
## 1                                  1
## 2                               0.93
## 3                               0.86
## 4                               0.79
## 5                               0.66
## 6                               0.59
## 7                               0.46
## 8                               0.39
## 9                               0.29
```

4.7(a) Since the diabetics needed to survive long enough from birth until the study began, the data is left truncated. Construct a table showing the number of subjects at risk, Y, as a function of age.

```
#above code and data match output in lecture slide 33 output table  - now try problem data
df2_prob_LT=getKM_LT_Table(df2_prob,1)
show(df2_prob_LT)
```

```
##    tj ej cj nj c_tj-1   s_tj
## 1   0  0  0  3            1
## 2  60  1  0  5    4/5    0.8
## 3  62  1  0  9    8/9 0.7111
## 4  63  1  0 10   9/10   0.64
## 5  65  2  0 10   8/10  0.512
## 6  66  1  0 10   9/10 0.4608
## 7  68  2  0 13  11/13 0.3899
## 8  69  2  2 14  12/14 0.3342
## 9  70  2  0 13  11/13 0.2828
## 10 71  2  0 14  12/14 0.2424
## 11 72  2  1 14  12/14 0.2078
## 12 73  1  1 13  12/13 0.1918
## 13 74  1  1 12  11/12 0.1758
## 14 76  1  1 11  10/11 0.1598
## 15 77  1  0 10   9/10 0.1438
```

```
df2_prob_censored_noLT_KM=getKMTableNoCensorRemoval(df2_prob_censored_noLT,"+")
show(df2_prob_censored_noLT_KM)
```

```
##    orderedEventTimes_tj eventsAtEventTime_ej
## 1                     0                    0
## 2                    60                    1
## 3                    62                    1
## 4                    63                    1
## 5                    65                    2
## 6                    66                    1
## 7                    68                    2
## 8                    69                    2
## 9                    70                    2
## 10                   71                    2
## 11                   72                    2
## 12                   73                    1
## 13                   74                    1
## 14                   76                    1
## 15                   77                    1
##    censoredObservationsInInterval_cj inRiskSetAtTime_nj
## 1                                  0                30
## 2                                  0                30
## 3                                  0                29
## 4                                  0                28
## 5                                  0                27
## 6                                  0                25
## 7                                  0                24
## 8                                  2                22
## 9                                  0                18
## 10                                 0                16
## 11                                 1                14
## 12                                 1                11
## 13                                 1                 9
## 14                                 1                 7
## 15                                 0                 5
##    kaplanMeirSurvivalCurveAtTime_s_tj-1 c_tj-1
```

```
## 1                                      -  30/30
## 2                                      1  29/30
## 3                                   0.97  28/29
## 4                                   0.94  27/28
## 5                                   0.91  25/27
## 6                                   0.84  24/25
## 7                                   0.81  22/24
## 8                                   0.74  20/22
## 9                                   0.67  16/18
## 10                                   0.6  14/16
## 11                                  0.52  12/14
## 12                                  0.45  10/11
## 13                                  0.41    8/9
## 14                                  0.36    6/7
## 15                                  0.31    4/5
##    kaplanMeirSurvivalCurveAtTime_s_tj
## 1                                   1
## 2                                0.97
## 3                                0.94
## 4                                0.91
## 5                                0.84
## 6                                0.81
## 7                                0.74
## 8                                0.67
## 9                                 0.6
## 10                               0.52
## 11                               0.45
## 12                               0.41
## 13                               0.36
## 14                               0.31
## 15                               0.25
```