

SAS Program Notes

Biostatistics: A Guide to Design, Analysis, and Discovery

Chapter 11: Analysis of Survival Data

In addition to these notes, we recommend reading **Survival Analysis Using the SAS System A Practical Guide** by Paul D. Allison.

Note 11.1 – Life Table Method of Calculating Survival Probabilities

PROC LIFETEST is the SAS procedure which is used in the nonparametric analysis of life tables. In this section, we show its use in performing the life-table method of calculating survival probabilities for the data in Example 11.1. Table 11.1 presents the data on survival times for ovarian cancer patients.

In SAS commands following **PROC LIFETEST**, we use the **TIME** statement followed by the variable representing time and the variable following the * is the variable representing the censor status. The value in the parentheses after censoring indicator variable is the code used to indicate if that observation was censored or not. It must be a numeric value. In this case, we use **STATUS** as our censoring variable, and it takes a value of '0' if that observation was censored and a value of '1' if otherwise. The **INTERVALS** option specifies the time intervals to be used in the analysis. The **METHOD** option tells SAS to use the actuarial (life-table) method of analysis. If **METHOD** is not specified, then the product-limit method is used. In the output, SAS creates Table 11.2 and Table 11.3 as well as providing an estimate of the pdf for the time variable.

SAS commands:

```
DATA OVARIAN_CANCER;
  INPUT TIME STATUS NUMBER;
DATALINES;
0.5 1 1421
0.5 0 68
1.5 1 335
1.5 0 56
2.5 1 132
2.5 0 101
3.5 1 64
3.5 0 57
4.5 1 44
4.5 0 60
5.5 1 20
5.5 0 51
6.5 1 19
6.5 0 45
7.5 1 14
7.5 0 33
8.5 1 7
8.5 0 35
9.5 1 7
```

```

9.5 0 28
10.5 1 5
10.5 0 18
11.5 1 5
11.5 0 21
12.5 1 1
12.5 0 15
13.5 1 3
13.5 0 16
14.5 1 1
14.5 0 13
15.5 1 0
15.5 0 7
16.5 1 0
16.5 0 9

```

```

;
PROC LIFETEST METHOD=LIFE INTERVALS=(0 TO 16 BY 1);
  TIME TIME*STATUS(0);
  FREQ NUMBER;
RUN;

```

SAS output:

The SAS System
The LIFETEST Procedure

Life Table Survival Estimates

Interval [Lower, Upper)	Number Failed	Number Censored	Effective Sample Size	Conditional Probability of Failure	Conditional Probability		Survival	Failure
					Standard Error			
0	1	1421	68	2677.0	0.5308	0.00965	1.0000	0
1	2	335	56	1194.0	0.2806	0.0130	0.4692	0.5308
2	3	132	101	780.5	0.1691	0.0134	0.3375	0.6625
3	4	64	57	569.5	0.1124	0.0132	0.2805	0.7195
4	5	44	60	447.0	0.0984	0.0141	0.2489	0.7511
5	6	20	51	347.5	0.0576	0.0125	0.2244	0.7756
6	7	19	45	279.5	0.0680	0.0151	0.2115	0.7885
7	8	14	33	221.5	0.0632	0.0163	0.1971	0.8029
8	9	7	35	173.5	0.0403	0.0149	0.1847	0.8153
9	10	7	28	135.0	0.0519	0.0191	0.1772	0.8228
10	11	5	18	105.0	0.0476	0.0208	0.1680	0.8320
11	12	5	21	80.5	0.0621	0.0269	0.1600	0.8400
12	13	1	15	57.5	0.0174	0.0172	0.1501	0.8499
13	14	3	16	41.0	0.0732	0.0407	0.1475	0.8525
14	15	1	13	23.5	0.0426	0.0416	0.1367	0.8633
15	16	0	7	12.5	0	0	0.1309	0.8691
16	.	0	9	4.5	0	0	0.1309	0.8691

Evaluated at the Midpoint of the Interval

Interval [Lower, Upper)	Survival Standard Error	Median Residual Lifetime	Median Standard Error	PDF		Hazard	Hazard Standard Error
				PDF	Standard Error		

0	1	0	0.9419	0.0182	0.5308	0.00965	0.722604	0.017874
1	2	0.00965	3.5856	0.2771	0.1316	0.00667	0.326352	0.017592
2	3	0.00924	7.9202	0.6574	0.0571	0.00479	0.184745	0.016011
3	4	0.00891	10.6725	0.5445	0.0315	0.00384	0.11907	0.014857
4	5	0.00874	.	.	0.0245	0.00361	0.103529	0.015587
5	6	0.00862	.	.	0.0129	0.00285	0.059259	0.013245
6	7	0.00860	.	.	0.0144	0.00324	0.07037	0.016134
7	8	0.00862	.	.	0.0125	0.00327	0.065268	0.017434
8	9	0.00870	.	.	0.00745	0.00278	0.041176	0.01556
9	10	0.00879	.	.	0.00919	0.00341	0.053232	0.020113
10	11	0.00899	.	.	0.00800	0.00352	0.04878	0.021809
11	12	0.00925	.	.	0.00994	0.00434	0.064103	0.028653
12	13	0.00969	.	.	0.00261	0.00259	0.017544	0.017543
13	14	0.00986	.	.	0.0108	0.00604	0.075949	0.043818
14	15	0.0109	.	.	0.00582	0.00571	0.043478	0.043468
15	16	0.0119	.	.	0	.	0	.
16	.	0.0119

The LIFETEST Procedure

Summary of the Number of Censored and Uncensored Values

Total	Failed	Censored	Percent Censored
2711	2078	633	23.35

NOTE: There were 2 observations with missing values, negative time values or frequency values less than 1.

Note 11.2 – The Product Limit Method of Calculating Survival Probabilities

PROC LIFETEST also can perform the product-limit method of analysis of survival tables just by specifying **METHOD = KM**. As above, the **TIME** statement identifies the time variable and the variable following the * is the variable indicating whether or not the time is right-censored. The value in the parentheses is the value used to indicate the time is censored, and it must be numeric. In Example 11.2, we present data on times to relapse for 14 alcohol-dependent patients shown in Table 11.4. The variable **SEX** is coded as '1' for Female and '2' for Male.

SAS commands:

```
DATA ALCOHOL;
  INPUT TIME RELAPSE SEX;
DATALINES;
  4 1 2
  6 1 1
  6 1 2
  9 0 2
 10 1 1
 14 0 2
 16 1 2
 17 0 2
```

```

19 1 1
20 1 1
28 1 2
31 1 1
34 0 1
47 0 1

```

```

;
PROC LIFETEST METHOD=KM;
  TIME TIME*RELAPSE(0);
RUN;

```

SAS output:

The SAS System
The LIFETEST Procedure

Product-Limit Survival Estimates

TIME	Survival	Failure	Survival Standard Error	Number Failed	Number Left
0.0000	1.0000	0	0	0	14
4.0000	0.9286	0.0714	0.0688	1	13
6.0000	.	.	.	2	12
6.0000	0.7857	0.2143	0.1097	3	11
9.0000*	.	.	.	3	10
10.0000	0.7071	0.2929	0.1237	4	9
14.0000*	.	.	.	4	8
16.0000	0.6188	0.3813	0.1362	5	7
17.0000*	.	.	.	5	6
19.0000	0.5156	0.4844	0.1475	6	5
20.0000	0.4125	0.5875	0.1497	7	4
28.0000	0.3094	0.6906	0.1435	8	3
31.0000	0.2063	0.7938	0.1274	9	2
34.0000*	.	.	.	9	1
47.0000*	.	.	.	9	0

NOTE: The marked survival times are censored observations.

Summary Statistics for Time Variable TIME

Percent	Quartile Estimates		
	Point Estimate	95% Confidence Interval [Lower Upper)	
75	31.0000	19.0000	.
50	20.0000	10.0000	31.0000
25	10.0000	6.0000	20.0000

Mean	Standard Error
19.8429	2.9840

NOTE: The mean survival time and its standard error were underestimated because the largest observation was censored and the estimation was restricted to the largest event time.

The LIFETEST Procedure
Summary of the Number of Censored and Uncensored Values

Total	Failed	Censored	Percent Censored
14	9	5	35.71

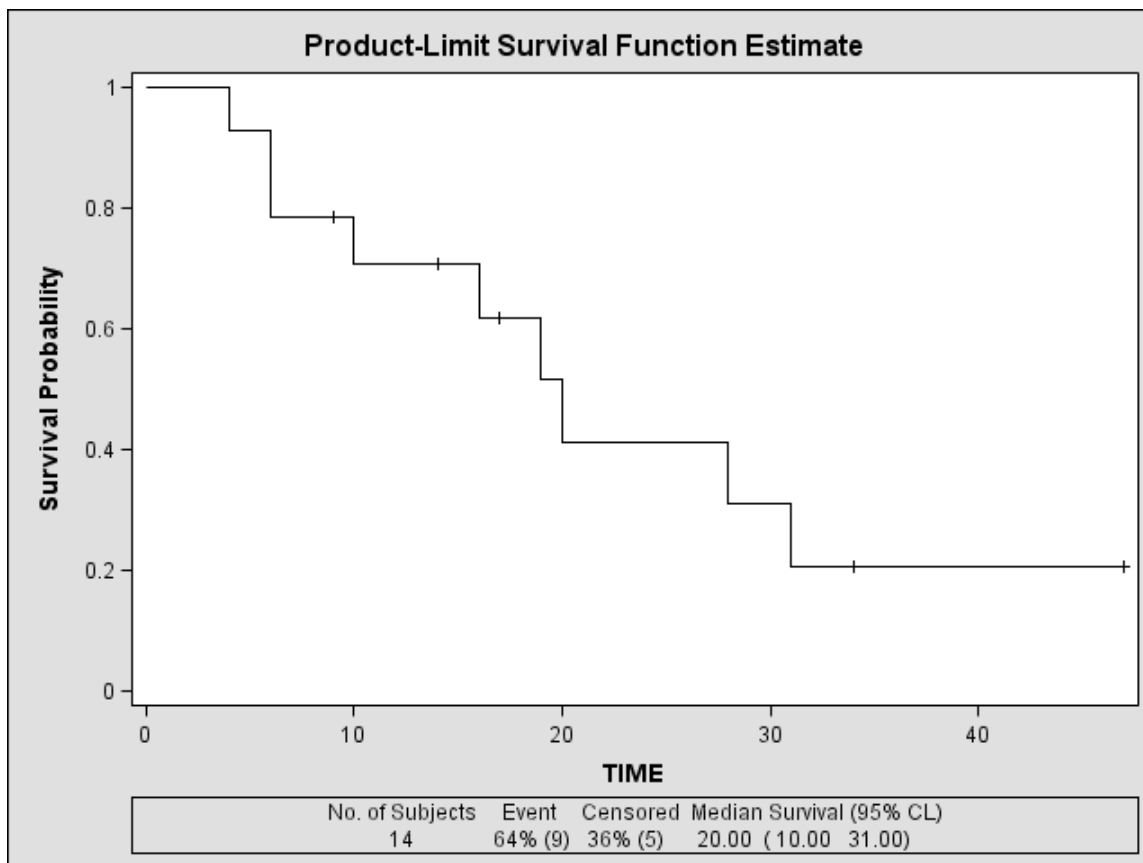
Note that the sample mean shown here is 19.8429. This value is different from the value of 18.4 shown in the text on page 309. The text value is wrong.

In the SAS commands below, we specify **METHOD=KM**, therefore the **PLOTS=(S)** option asks SAS to plot a Kaplan-Meier curve.

SAS commands:

```
GOPTIONS DEVICE= GIF VPOS= 24 HPOS= 75 VSIZE= 5 HSIZE= 6 FTEXT=COMPLEX;
ODS HTML;
ODS GRAPHICS ON;
ODS NOPTITLE;
ODS SELECT SURVIVAL;
PROC LIFETEST DATA=ALCOHOL METHOD=KM PLOTS=(S);
    TIME TIME*RELAPSE(0);
RUN;
ODS GRAPHICS OFF;
ODS HTML CLOSE;
```

SAS output:



Note 11.3 – Comparing Survival Curves

When **STRATA** is used, the survival probabilities and medians and restricted means are estimated separately for each level of variable following the **STRATA** statement. In the SAS commands below, we use the variable **SEX** following **STRATA** to obtain survival probabilities for females and males separately. In Example 11.4, we conduct the log-rank test to compare the survival function between males and females. This can be accomplished in the **STRATA** statement. After the variable **SEX**, we use a forward slash '/' to specify options, then we use **TEST=** followed by the specific test in parentheses. Notice that **LOGRANK** is in parentheses since it is the test that we are interested in conducting. Some other possible options are **ALL**, **FLEMING**, **LR**, **MODIFIEDPETO**, **MODPETO**, **PETO**, **TARONE** and **WILCOXON**.

SAS commands:

```
PROC LIFETEST DATA=ALCOHOL;  
TIME TIME*RELAPSE(0);  
STRATA SEX/TEST=(LOGRANK);  
RUN;
```

SAS output:

The SAS System
Stratum 1: SEX = 1
Product-Limit Survival Estimates

TIME	Survival	Failure	Survival Standard Error	Number Failed	Number Left
0.0000	1.0000	0	0	0	7
6.0000	0.8571	0.1429	0.1323	1	6
10.0000	0.7143	0.2857	0.1707	2	5
19.0000	0.5714	0.4286	0.1870	3	4
20.0000	0.4286	0.5714	0.1870	4	3
31.0000	0.2857	0.7143	0.1707	5	2
34.0000*	.	.	.	5	1
47.0000*	.	.	.	5	0

NOTE: The marked survival times are censored observations.

Summary Statistics for Time Variable TIME

Percent	Quartile Estimates		
	Point Estimate	95% Confidence Interval [Lower Upper)	
75	.	19.0000	.
50	20.0000	10.0000	.
25	10.0000	6.0000	31.0000

Mean	Standard Error
21.1429	4.0747

NOTE: The mean survival time and its standard error were underestimated because the largest observation was censored and the estimation was restricted to the largest event time.

Stratum 2: SEX = 2

Product-Limit Survival Estimates

TIME	Survival	Failure	Survival Standard Error	Number Failed	Number Left
0.0000	1.0000	0	0	0	7
4.0000	0.8571	0.1429	0.1323	1	6
6.0000	0.7143	0.2857	0.1707	2	5
9.0000*	.	.	.	2	4
14.0000*	.	.	.	2	3
16.0000	0.4762	0.5238	0.2253	3	2
17.0000*	.	.	.	3	1
28.0000	0	1.0000	0	4	0

NOTE: The marked survival times are censored observations.

Summary Statistics for Time Variable TIME
Quartile Estimates

Percent	Point	95% Confidence Interval	
	Estimate	[Lower	Upper)
75	28.0000	16.0000	28.0000
50	16.0000	6.0000	28.0000
25	6.0000	4.0000	28.0000

Mean	Standard Error
18.5714	4.6199

Summary of the Number of Censored and Uncensored Values

Stratum	SEX	Total	Failed	Censored	Percent Censored
1	1	7	5	2	28.57
2	2	7	4	3	42.86

Total		14	9	5	35.71

Testing Homogeneity of Survival Curves for TIME over Strata

Rank Statistics

SEX	Log-Rank
1	-1.1853
2	1.1853

Covariance Matrix for the Log-Rank Statistics

SEX	1	2
1	1.66639	-1.66639
2	-1.66639	1.66639

Test of Equality over Strata			
Test	Chi-Square	DF	Pr >
Log-Rank	0.8430	1	0.3585

The following SAS commands can be used to plot Kaplan-Meier survival curves by sex. Notice that we are using a **PROC FORMAT** statement to assign labels to the values of the **SEX** variable.

SAS commands:

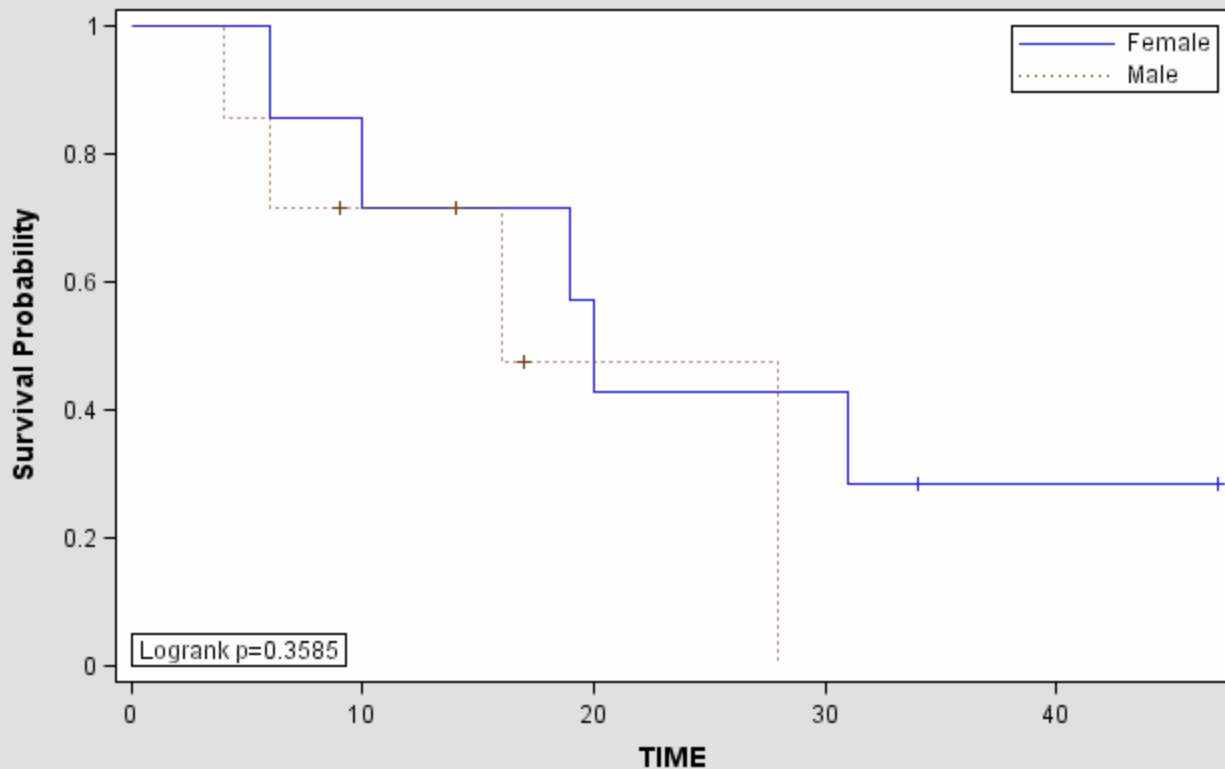
```

DATA ALCOHOL;
INPUT TIME RELAPSE SEX;
DATALINES;
4 1 2
6 1 1
6 1 2
9 0 2
10 1 1
14 0 2
16 1 2
17 0 2
19 1 1
20 1 1
28 1 2
31 1 1
34 0 1
47 0 1
;
PROC FORMAT;
  VALUE SEX 1 = 'Female'
          2 = 'Male';
RUN;
GOPTIONS DEVICE= GIF VPOS= 24 HPOS= 75 VSIZE= 5 HSIZE= 6 FTEXT=COMPLEX;
ODS HTML;
ODS GRAPHICS ON;
ODS NOPTITLE;
ODS SELECT SURVIVAL;
PROC LIFETEST DATA=ALCOHOL METHOD=KM NOPRINT PLOTS=(S);
  TIME TIME*RELAPSE(0);
  FORMAT SEX SEX.;
  STRATA SEX;
RUN;
ODS GRAPHICS OFF;
ODS HTML CLOSE;

```

SAS output:

Product-Limit Survival Function Estimates



	No. of Subjects	Event	Censored	Median Survival (95% CL)
Female	7	71% (5)	29% (2)	20.00 (10.00 NA)
Male	7	57% (4)	43% (3)	16.00 (6.00 28.00)