stci — Confidence intervals for means and percentiles of survival time

Description

stci computes means and percentiles of survival time, standard errors, and confidence intervals. For multiple-event data, survival time is the time until a failure.

stci can be used with single- or multiple-record or single- or multiple-failure st data.

Quick start

Median survival time with standard error and 95% confidence interval using stset data
  stci

Also report medians with standard errors and confidence intervals for each level of v1
  stci, by(v1)

Same as above, but report 99% confidence intervals
  stci, by(v1) level(99)

Report the 75th percentile of survival times instead of the medians
  stci, by(v1) p(75)

Mean survival time, computed by exponentially extending curve to zero if last follow-up time is censored
  stci, emean

Same as above, and plot the extended survivor function
  stci, emean graph

Menu

Statistics > Survival analysis > Summary statistics, tests, and tables > CIs for means and percentiles of survival time
Syntax

stci [if] [in] [ , options ]

<table>
<thead>
<tr>
<th>options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main</strong></td>
<td></td>
</tr>
<tr>
<td>by(varlist)</td>
<td>perform separate calculations for each group of varlist</td>
</tr>
<tr>
<td>median</td>
<td>calculate median survival times; the default</td>
</tr>
<tr>
<td>rmean</td>
<td>calculate mean survival time restricted to longest follow-up time</td>
</tr>
<tr>
<td>emean</td>
<td>calculate the mean survival time by exponentially extending the survival curve to zero</td>
</tr>
<tr>
<td>p(#)</td>
<td>compute the # percentile of survival times</td>
</tr>
<tr>
<td>ccorr</td>
<td>calculate the standard error for rmean using a continuity correction</td>
</tr>
<tr>
<td>noshow</td>
<td>do not show st setting information</td>
</tr>
<tr>
<td>dd(#)</td>
<td>set maximum number of decimal digits to report</td>
</tr>
<tr>
<td>level(#)</td>
<td>set confidence level; default is level(95)</td>
</tr>
<tr>
<td>graph</td>
<td>plot exponentially extended survivor function</td>
</tr>
<tr>
<td>tmax(#)</td>
<td>set maximum analysis time of # to be plotted</td>
</tr>
<tr>
<td><strong>Plot</strong></td>
<td></td>
</tr>
<tr>
<td>cline_options</td>
<td>affect rendition of the plotted lines</td>
</tr>
<tr>
<td><strong>Add plots</strong></td>
<td></td>
</tr>
<tr>
<td>addplot(plot)</td>
<td>add other plots to the generated graph</td>
</tr>
<tr>
<td><strong>Y axis, X axis, Titles, Legend, Overall</strong></td>
<td></td>
</tr>
<tr>
<td>twoway_options</td>
<td>any options other than by() documented in [G-3] twoway_options</td>
</tr>
</tbody>
</table>

You must stset your data before using stci; see [ST] stset.
by and collect are allowed; see [U] 11.1.10 Prefix commands.

Options

by(varlist) specifies that separate calculations be made for each group identified by equal values of the variables in varlist, resulting in separate summaries and an overall total. varlist may contain any number of variables, each of which may be string or numeric.

median specifies median survival times. This is the default.

rmean and emean specify mean survival times. If the longest follow-up time is censored, emean (extended mean) computes the mean survival by exponentially extending the survival curve to zero, and rmean (restricted mean) computes the mean survival time restricted to the longest follow-up time. If the longest follow-up time is a failure, the restricted mean survival time and the extended mean survival time are equal.

p(#) specifies the percentile of survival time to be computed. For example, p(25) will compute the 25th percentile of survival times, and p(75) will compute the 75th percentile of survival times. Specifying p(50) is the same as specifying the median option.

ccorr specifies that the standard error for the restricted mean survival time be computed using a continuity correction. ccorr is valid only with the rmean option.
noshow prevents stci from showing the key st variables. This option is seldom used because most people type stset, show or stset, noshow to set whether they want to see these variables mentioned at the top of the output of every st command; see [ST] stset.

dd(\#) specifies the maximum number of decimal digits to be reported for standard errors and confidence intervals. This option affects only how values are reported and not how they are calculated.

level(\#) specifies the confidence level, as a percentage, for confidence intervals. The default is level(95) or as set by set level; see [U] 20.8 Specifying the width of confidence intervals.

graph specifies that the exponentially extended survivor function be plotted. This option is valid only when the emean option is also specified and is not valid in conjunction with the by() option.

tmax(\#) is for use with the graph option. It specifies the maximum analysis time to be plotted.

cline_options affect the rendition of the plotted lines; see [G-3] cline_options.

addplot(plot) provides a way to add other plots to the generated graph; see [G-3] addplot_option.

twoway_options are any of the options documented in [G-3] twoway_options, excluding by(). These include options for titling the graph (see [G-3] title_options) and for saving the graph to disk (see [G-3] saving_option).

Remarks and examples

Remarks are presented under the following headings:

Single-failure data
Multiple-failure data
Single-failure data

Here is an example of `stci` with single-record survival data:

```
. use https://www.stata-press.com/data/r18/page2
. stset, noshow
. stci

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>40</td>
<td>232</td>
<td>2.562933</td>
</tr>
</tbody>
</table>

. stci, by(group)

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>216</td>
<td>7.661029</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>233</td>
<td>3.081611</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>232</td>
<td>2.562933</td>
</tr>
</tbody>
</table>
```

In the example above, we obtained the median survival time, by default.

To obtain the 25th or any other percentile of survival time, specify the `p(#)` option.

```
. stci, p(25)

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>25%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>40</td>
<td>198</td>
<td>10.76878</td>
</tr>
</tbody>
</table>

. stci, p(25) by(group)

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>25%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>190</td>
<td>13.43601</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>232</td>
<td>19.42378</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>198</td>
<td>10.76878</td>
</tr>
</tbody>
</table>
```

The $p$-percentile of survival time is the analysis time at which $p\%$ of subjects have failed and $1 - p\%$ have not. In the table above, 25% of subjects in group 1 failed by time 190, whereas 25% of subjects in group 2 failed by time 232, indicating a better survival experience for this group.
We can verify the quantities reported by `stci` by plotting and examining the Kaplan–Meier survival curves.

```
. sts graph, by(group)
```

The mean survival time reported by `rmean` is calculated as the area under the Kaplan–Meier survivor function. If the observation with the largest analysis time is censored, the survivor function does not go to zero. Consequently, the area under the curve underestimates the mean survival time.

In the graph above, the survival probability for `group = 1` goes to 0 at analysis time 344, but the survivor function for `group = 2` never goes to 0. For these data, the mean survival time for `group = 1` will be properly estimated, but it will be underestimated for `group = 2`. When we specify the `rmean` option, Stata informs us if any of the mean survival times is underestimated.

```
. stci, rmean by(group)
```

<table>
<thead>
<tr>
<th>group</th>
<th>Number of restricted subjects</th>
<th>Restricted mean</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>218.7566</td>
<td>9.122424</td>
<td>200.877 236.636</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>241.8571(*)</td>
<td>11.34728</td>
<td>219.617 264.097</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>231.3522(*)</td>
<td>7.700819</td>
<td>216.259 246.446</td>
</tr>
</tbody>
</table>

(*): largest observed analysis time is censored, mean is underestimated

Stata flagged the mean for `group = 2` and the overall mean as being underestimated.

If the largest observed analysis time is censored, `stci`’s `emean` option extends the survivor function from the last observed time to zero by using an exponential function and computes the area under the entire curve.

```
. stci, emean
```

<table>
<thead>
<tr>
<th>Number of extended subjects</th>
<th>Extended mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>40</td>
</tr>
</tbody>
</table>

The resulting area must be evaluated with care because it is an ad hoc approximation that can at times be misleading. We recommend that you plot and examine the extended survivor function. This is facilitated by the use of `stci`’s `graph` option.
. stci, emean graph

Exponentially extended survivor function

<table>
<thead>
<tr>
<th>Analysis time</th>
<th>Survival probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>0.8</td>
</tr>
<tr>
<td>400</td>
<td>0.6</td>
</tr>
<tr>
<td>600</td>
<td>0.4</td>
</tr>
<tr>
<td>800</td>
<td>0.2</td>
</tr>
</tbody>
</table>

stci also works with multiple-record survival data. Here is a summary of the multiple-record Stanford heart transplant data introduced in [ST] stset:

. use https://www.stata-press.com/data/r18/stan3
(Heart transplant data)
. stset, noshow
. stci

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>103</td>
<td>100</td>
<td>38.6425</td>
</tr>
</tbody>
</table>

stci with the by() option may produce results with multiple-record data that you might think are in error:

. stci, by(posttran)

<table>
<thead>
<tr>
<th>posttran</th>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>103</td>
<td>149</td>
<td>43.81077</td>
<td>69</td>
</tr>
<tr>
<td>1</td>
<td>69</td>
<td>96</td>
<td>58.71712</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>100</td>
<td>38.64425</td>
<td>69</td>
</tr>
</tbody>
</table>

For the number of subjects, 103 + 69 ≠ 103. The posttran variable is not constant for the subjects in this dataset:

. stvary posttran

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subjects for whom the variable is</th>
<th>never</th>
<th>always</th>
<th>sometimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>posttran</td>
<td>constant</td>
<td>varying</td>
<td>missing</td>
<td>missing</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>69</td>
<td>103</td>
<td>0</td>
</tr>
</tbody>
</table>
In this dataset, subjects have one or two records. All subjects were eligible for heart transplantation. They have one record if they die or are lost because of censoring before transplantation, and they have two records if the operation was performed. Then the first record records their survival up to transplantation, and the second records their subsequent survival. posttran is 0 in the first record and 1 in the second.

Therefore, all 103 subjects have records with posttran = 0, and when stci reported results for this group, it summarized the pretransplantation survival. The median survival time was 149 days.

The posttran = 1 line of stci’s output summarizes the posttransplantation survival: 69 patients underwent transplantation, and the median survival time was 96 days. For these data, this is not 96 more days, but 96 days in total. That is, the clock was not reset on transplantation. Thus, without attributing cause, we can describe the differences between the groups as an increased hazard of death at early times followed by a decreased hazard later.

Multiple-failure data

If you simply type stci with multiple-failure data, the reported survival time is the survival time to the first failure, assuming that the hazard function is not indexed by number of failures.

Here we have some multiple-failure data:

```
. use https://www.stata-press.com/data/r18/mfail2
. st
-> stset t, id(id) failure(d) time0(t0) exit(time .) noshow
Survival-time data settings
   ID variable: id
Failure event: d!=0 & d<.
   Observed time interval: (t0, t]
   Exit on or before: time .
. stci
```

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>926</td>
<td>420</td>
<td>13.42537</td>
</tr>
</tbody>
</table>

To understand this output, let’s also obtain output for each failure separately:

```
. stgen nf = nfailures()
. stci, by(nf)
```

<table>
<thead>
<tr>
<th>nf</th>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>926</td>
<td>399</td>
<td>13.91796</td>
<td>381</td>
</tr>
<tr>
<td>1</td>
<td>529</td>
<td>503</td>
<td>28.53425</td>
<td>425</td>
</tr>
<tr>
<td>2</td>
<td>221</td>
<td>687</td>
<td>69.38412</td>
<td>549</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Total</td>
<td>926</td>
<td>420</td>
<td>13.42537</td>
<td>394</td>
</tr>
</tbody>
</table>

The stgen command added, for each subject, a variable containing the number of previous failures. nf is 0 for a subject, up to and including the first failure. Then nf is 1 up to and including the second failure, and then it is 2, and so on; see [ST] stgen.

The first line, corresponding to nf = 0, states that among those who had experienced no failures yet, the median time to first failure is 399.
Similarly, the second line, corresponding to \( \text{nf} = 1 \), is for those who have already experienced one failure. The median time of second failures is 503.

When we simply typed \texttt{stci} , we obtained the same information shown as the total line of the more detailed output. The total survival time distribution is an estimate of the distribution of the time to first failure, assuming that the hazard function, \( h(t) \), is the same across failures—that the second failure is no different from the first failure. This is an odd definition of \textit{same} because the clock, \( t \), is not reset in \( h(t) \) upon failure. The hazard of a failure—any failure—at time \( t \) is \( h(t) \).

Another definition of \textit{same} would have it that the hazard of a failure is given by \( h(\tau) \), where \( \tau \) is the time since the last failure—that the process resets itself. These definitions are different unless \( h() \) is a constant function of \( t \).

Let’s examine this multiple-failure data, assuming that the process repeats itself. The key variables in this \textit{st} data are \( \text{id} \), \( t0 \), \( t \), and \( d \):

\[
\begin{align*}
\text{. st} \\
\rightarrow \text{stset } t, \text{id(id)} \text{ failure(d)} \text{ time0(t0)} \text{ exit(time .) noshow}
\end{align*}
\]

Survival-time data settings

\[
\begin{align*}
\text{ID variable: id} \\
\text{Failure event: d!=0 & d<.} \\
\text{Observed time interval: (t0, t]} \\
\text{Exit on or before: time .}
\end{align*}
\]

Our goal, for each subject, is to reset \( t0 \) and \( t \) to 0 after every failure event. We must trick Stata, or at least trick \texttt{stset} because it will not let us set data where the same subject has multiple records summarizing the overlapping periods. The trick is create a new \texttt{id} variable that is different for every \( \text{id–nf} \) combination (remember, \( \text{nf} \) is the variable we previously created that records the number of prior failures). Then each of the “new” subjects can have their clock start at time 0:

\[
\begin{align*}
\text{. egen newid = group(id nf)} \\
\text{. by newid: replace t = t - t0[1]} \\
\text{(808 real changes made)} \\
\text{. by newid: gen newt0 = t0 - t0[1]} \\
\text{. stset t, failure(d) id(newid) time0(newt0)}
\end{align*}
\]

Survival-time data settings

\[
\begin{align*}
\text{ID variable: newid} \\
\text{Failure event: d!=0 & d<.} \\
\text{Observed time interval: (newt0, t]} \\
\text{Exit on or before: failure}
\end{align*}
\]

\[
\begin{align*}
\text{1,734 total observations} \\
\text{0 exclusions}
\end{align*}
\]

\[
\begin{align*}
\text{1,734 observations remaining, representing} \\
\text{1,734 subjects} \\
\text{808 failures in single-failure-per-subject data} \\
\text{435,444 total analysis time at risk and under observation}
\end{align*}
\]

\[
\begin{align*}
\text{At risk from } t = & 0 \\
\text{Earliest observed entry } t = & 0 \\
\text{Last observed exit } t = & 797
\end{align*}
\]

\texttt{stset} no longer thinks that we have multiple-failure data. Whereas with \texttt{id}, subjects had multiple failures, \texttt{newid} gives a unique identity to each \texttt{id–nf} combination. Each “new” subject has at most one failure.
. stci, by(nf)

<table>
<thead>
<tr>
<th>nf</th>
<th>Number of subjects</th>
<th>50%</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>926</td>
<td>399</td>
<td>13.91796</td>
<td>381</td>
</tr>
<tr>
<td>1</td>
<td>529</td>
<td>384</td>
<td>18.22987</td>
<td>359</td>
</tr>
<tr>
<td>2</td>
<td>221</td>
<td>444</td>
<td>29.80391</td>
<td>325</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 1734 404 10.29992 386 430

Compare this table with the one we previously obtained. The number of subjects is the same, but the survival times differ because now we measure the times from one failure to the next, whereas previously we measured the time from a fixed point. The time between events in these data appears to be independent of event number.

Similarly, we can obtain the mean survival time for these data restricted to the longest follow-up time:

. stci, rmean by(nf)

<table>
<thead>
<tr>
<th>nf</th>
<th>Number of subjects</th>
<th>Restricted mean</th>
<th>Std. err.</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>926</td>
<td>399.1802</td>
<td>8.872794</td>
<td>381.79 416.571</td>
</tr>
<tr>
<td>1</td>
<td>529</td>
<td>397.0077(*)</td>
<td>13.36058</td>
<td>370.821 423.194</td>
</tr>
<tr>
<td>2</td>
<td>221</td>
<td>397.8051(*)</td>
<td>25.78559</td>
<td>347.266 448.344</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td>471(*)</td>
<td>0</td>
<td>471     471</td>
</tr>
</tbody>
</table>

Total 1734 404.7006 7.021657 390.938 418.463

(*) largest observed analysis time is censored, mean is underestimated

**Stored results**

stci stores the following in r():

Scalars

- r(N_sub): number of subjects
- r(p#): #th percentile
- r(rmean): restricted mean
- r(emean): extended mean
- r(se): standard error
- r(lb): lower bound of CI
- r(ub): upper bound of CI

**Methods and formulas**

The percentiles of survival times are obtained from $S(t)$, the Kaplan–Meier product-limit estimate of the survivor function. The 25th percentile, for instance, is obtained as the minimum value of $t$ such that $S(t) \leq 0.75$. The restricted mean is obtained as the area under the Kaplan–Meier product-limit survivor curve. The extended mean is obtained by extending the Kaplan–Meier product-limit survivor curve to zero by using an exponentially fitted curve and then computing the area under the entire curve. If the longest follow-up time ends in failure, the Kaplan–Meier product-limit survivor curve goes to zero, and the restricted mean and extended mean are identical.
The large-sample standard error for the $p$th percentile of the distribution is given by Collett (2015, 38) and Klein and Moeschberger (2003, 122) as

$$\sqrt{\text{Var}\{\hat{S}(t_p)\}} \hat{f}(t_p)$$

where $\text{Var}\{\hat{S}(t_p)\}$ is the Greenwood pointwise variance estimate for $\hat{S}(t_p)$ and $\hat{f}(t_p)$ is the estimated density function at the $p$th percentile.

Confidence intervals, however, are not calculated based on this standard error. For a given confidence level, the upper confidence limit for the $p$th percentile is defined as the first time at which the upper confidence limit for $S(t)$ (based on a $\ln\{-\ln S(t)\}$ transformation) is less than or equal to $1 - p/100$, and, similarly, the lower confidence limit is defined as the first time at which the lower confidence limit of $S(t)$ is less than or equal to $1 - p/100$.

The restricted mean is obtained as the area under the Kaplan–Meier product-limit survivor curve. The extended mean is obtained by extending the Kaplan–Meier product-limit survivor curve to zero by using an exponentially fitted curve and then computing the area under the entire curve. If the longest follow-up time ends in failure, the Kaplan–Meier product-limit survivor curve goes to zero, and the restricted mean and the extended mean are identical.

The standard error for the estimated restricted mean is computed as given by Klein and Moeschberger (2003, 118) and Collett (2015, 390):

$$\hat{SE} = \sum_{i=1}^{D} \frac{\hat{A}_i}{R_i(R_i - d_i)}$$

where the sum is over all distinct failure times, $\hat{A}_i$ is the estimated area under the curve from time $i$ to the maximum follow-up time, $R_i$ is the number of subjects at risk at time $i$, and $d_i$ is the number of failures at time $i$.

The $100(1 - \alpha)\%$ confidence interval for the estimated restricted mean is computed as

$$\hat{A}_i \pm Z_{1-\alpha/2}\hat{SE}$$

References


Also see

[ST] `stdescribe` — Describe survival-time data
[ST] `stir` — Report incidence-rate comparison
[ST] `stptime` — Calculate person-time, incidence rates, and SMR
[ST] `sts` — Generate, graph, list, and test the survivor and related functions
[ST] `stset` — Declare data to be survival-time data

[ST] `stvary` — Report variables that vary over time