Effectiveness of Stents in Treating Patients at Risk of Stroke

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Stents are devices put inside blood vessels that assist in patient recovery after cardiac events and reduce the risk of an additional heart attack or death. Many doctors have hoped that there would be similar benefits for patients at risk of stroke. Through statistical inference and procedure, this paper will attempt to answer the question: Does the use of stents reduce the risk of stroke?

An experiment has been conducted among 451 at-risk patients, who were randomly assigned to one of two groups - treatment group and control group. 224 patients were assigned to the treatment group and received a stent and medical management which included medications, management of risk factors, and help in lifestyle modification. 227 patients in the control group received the same medical management as the treatment group but did not receive stents. In this study, control group provided a reference point for the medical impact of stents in the treatment group. Researchers studied the effect of stents at two time points: 30 days after enrollment and 365 days after enrollment.

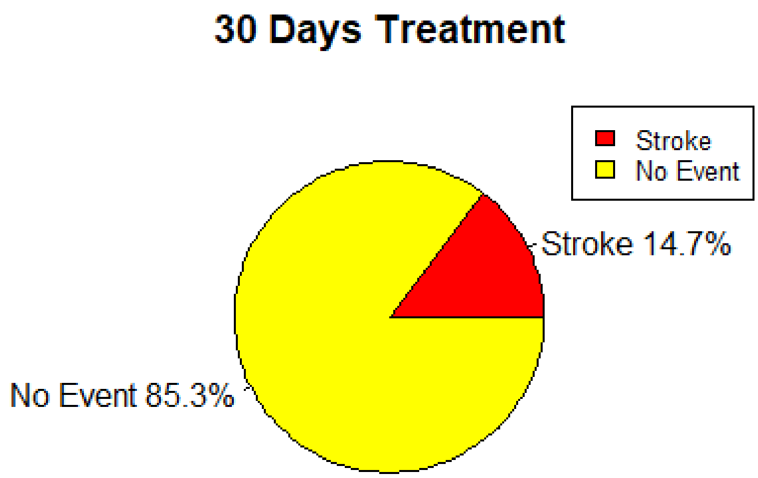
Let's first try to answer the question by looking at the results collected after 30 days of enrollment. Results for 0-30 days are shown in the following table and pie charts.

```r
# Extracting data from stent30.csv file
data_30 = read.csv("stent30.csv", header = TRUE)

# Patients assigned to treatment group
treatment = subset(data_30, group=="treatment")
treat_str_num = sum(treatment$'outcome'=="stroke")
treat_ne_num = sum(treatment$'outcome'=="no event")
treat_total = sum(treatment$'outcome' != "")
```

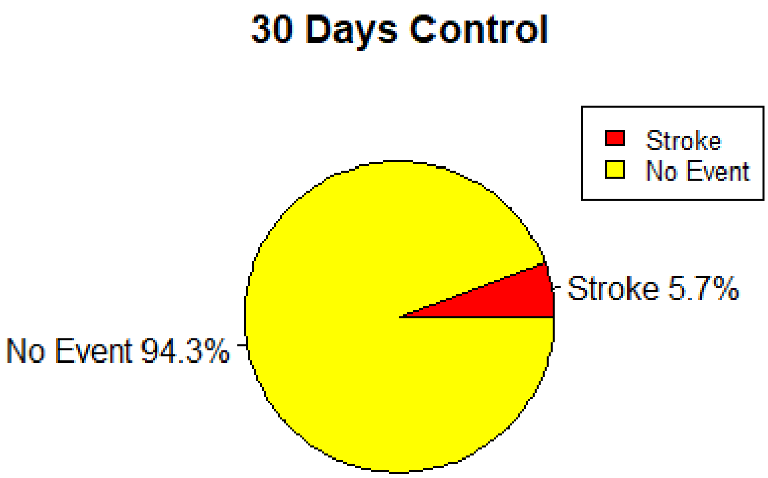
```r
# Patients assigned to control group
control = subset(data_30, group=="control")
cont_str_num = sum(control$'outcome'=="stroke")
cont_ne_num = sum(control$'outcome'=="no event")
cont_total = sum(control$'outcome' != "")

# Total outcome for patients in both groups
str_total = sum(data_30$'outcome'=="stroke")
ne_total = sum(data_30$'outcome'=="no event")

# Results table
table_30 = matrix(c(treat_str_num,cont_str_num,str_total,treat_ne_num, cont_n
e_num, ne_total), ncol=2, nrow=3)
colnames(table_30) = c("Stroke","No Event")
rownames(table_30) = c("Treatment","Control","Total")
table_30 = as.table(table_30)
names(dimnames(table_30)) = list("","0-30 Days")
table_30
```

```
##             0-30 Days
##              Stroke No Event
##   Treatment     33      191
##   Control       13      214
##   Total         46      405
```

```r
# Pie chart for treatment group
xa = c(treat_str_num,treat_ne_num)
labels_xa = c("Stroke", "No Event")
pct_xa = round(xa/sum(xa)*100, digits=1)

lbls_xa = paste(labels_xa, pct_xa)
lbls_xa = paste(lbls_xa, "%", sep="")

pie(xa, labels = lbls_xa, col = heat.colors(length(lbls_xa)), main = "30 Days
Treatment")
legend("topright", c("Stroke", "No Event"), cex = 0.8, fill = heat.colors(len
gth(xa)))
```




```r
# Pie chart for control group
xb = c(cont_str_num,cont_ne_num)
labels_xb = c("Stroke", "No Event")
pct_xb = round(xb/sum(xb)*100, digits=1)

lbls_xb = paste(labels_xb, pct_xb)
lbls_xb = paste(lbls_xb, "%", sep="")

pie(xb, labels = lbls_xb, col = heat.colors(length(lbls_xb)), main = "30 Days
Control")
legend("topright", c("Stroke", "No Event"), cex = 0.8, fill = heat.colors(len
gth(xb)))
```



Based on the given 0-30 days data, contrary to what doctors had expected, stents did not help the patients in reducing the risk of stroke.

So while the original concern was to test whether stents *decrease* the risk of strokes, since the data is clearly in the opposite direction of the prominent alternative hypothesis $p_1 < p_2$, where p_1 denotes the treatment group and p_2 denotes the control group, **two sided test must be used here**.

Two proportion hypothesis test can take place to see if the use of stents *has an effect* on the risk of stroke. Let the null hypothesis be that *the use of stents has no effect on the risk of stroke*. That is, the proportion of patients that experience stroke in the treatment group equals the proportion of patients that experience stroke in the control group.

$$H_0: p_1 = p_2$$

(where p_1 denotes the treatment group and p_2 denotes the control group.)

Let the alternative hypothesis be that *the use of stents does have an effect on the risk of stroke*. That is, the proportion of patients that experience stroke in the treatment group is different from the proportion of patients that experience stroke in the control group.

$$H_A: p_1 \neq p_2$$

(where p_1 denotes the treatment group and p_2 denotes the control group.)

33 of 224 patients assigned to treatment group experienced stroke during the first 30 days of enrollment, while 13 of 227 patients assigned to control group experienced stroke during the same period of time. So $\hat{p}_1$ and $\hat{p}_2$ are:

$$\hat{p}_1 = 33/224 = 14.7\% \text{ and } \hat{p}_2 = 13/227 = 5.7\%.$$

Let α =0.05 for this hypothesis testing. The 95% confidence interval is

$$(\hat{p}_1 - \hat{p}_2) \pm z * \sqrt{\frac{\hat{p}_1 (1 - \hat{p}_1)}{n_1} + \frac{\hat{p}_2 (1 - \hat{p}_2)}{n_2}}$$

$$(0.147 - 0.057) \pm 1.96 * \sqrt{\frac{0.147\ (0.853)}{224} + \frac{0.057\ (0.943)}{227}}$$

$$= 0.09 \pm 0.055$$

$$= (0.035, 0.145)$$

The z-statistic value and the p-value are:

```
# sample proportion for both groups
p1_hat = treat_str_num/treat_total
p2_hat = cont_str_num/cont_total
p_hat = (treat_str_num+cont_str_num)/(treat_total+cont_total)
z_stat = (p1_hat-p2_hat)/(sqrt((p_hat*(1-p_hat)*((1/treat_total)+(1/cont_tota
l)))))
z_stat

## [1] 3.15948
```

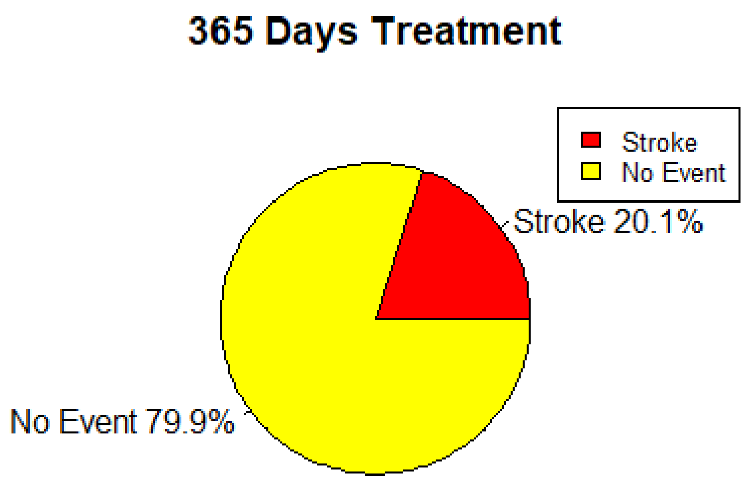
```
p_value = 2*(1-pnorm(z_stat))
p_value

## [1] 0.001580512
```

At α =0.05, since the p-value is < α, we reject the null hypothesis in favor of the alternative hypothesis. Following the 0-30 days data, it can be said that the proportion of patients that experienced stroke in the treatment group *is different* from the proportion of patients that experienced stroke in the control group with 95% confidence.

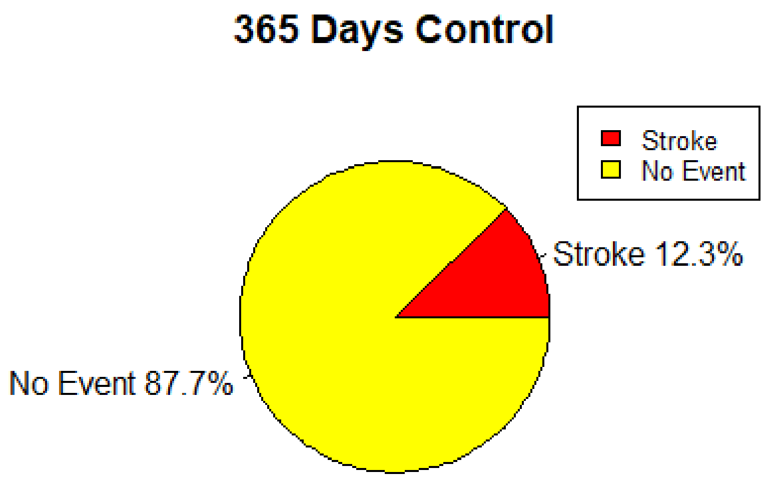
Now let's take a look at 0-365 days data to see if it offers the same conclusion:

```
# Extracting data from stent365.csv file
data_365 = read.csv("stent365.csv", header = TRUE)

# Patients assigned to treatment group
treatment = subset(data_365, group=="treatment")
treat_str_num = sum(treatment$'outcome'=="stroke")
treat_ne_num = sum(treatment$'outcome'=="no event")
treat_total = sum(treatment$'outcome' != "")

# Patients assigned to control group
control = subset(data_365, group=="control")
cont_str_num = sum(control$'outcome'=="stroke")
cont_ne_num = sum(control$'outcome'=="no event")
cont_total = sum(control$'outcome' != "")

# Results table
table_365 = matrix(c(treat_str_num,cont_str_num,str_total,treat_ne_num, cont_
ne_num, ne_total), ncol=2, nrow=3)
colnames(table_365) = c("Stroke","No Event")
rownames(table_365) = c("Treatment","Control","Total")
table_365 = as.table(table_365)
names(dimnames(table_365)) = list("","0-365 Days")
table_365

##             0-365 Days
##              Stroke No Event
##   Treatment     45      179
##   Control       28      199
##   Total         46      405

# Pie chart for treatment group
ya = c(treat_str_num,treat_ne_num)
labels_ya = c("Stroke", "No Event")
pct_ya = round(ya/sum(ya)*100, digits=1)
```

```
lbls_ya = paste(labels_ya, pct_ya)
lbls_ya = paste(lbls_ya, "%", sep="")

pie(ya, labels = lbls_ya, col = heat.colors(length(lbls_ya)), main = "365 Day
s Treatment")
legend("topright", c("Stroke", "No Event"), cex = 0.8, fill = heat.colors(len
gth(ya)))
```




```
# Pie chart for control group
yb = c(cont_str_num,cont_ne_num)
labels_yb = c("Stroke", "No Event")
pct_yb = round(yb/sum(yb)*100, digits = 1)

lbls_yb = paste(labels_yb, pct_yb)
lbls_yb = paste(lbls_yb, "%", sep="")

pie(yb, labels = lbls_yb, col = heat.colors(length(lbls_yb)), main = "365 Day
s Control")
legend("topright", c("Stroke", "No Event"), cex = 0.8, fill = heat.colors(len
gth(yb)))
```



For the same reason as above, **two sided test must be used here**.

The two proportion hypothesis test can again take place based on the given 0-365 days data, to see if the use of stents has an effect on the risk of stroke. Let the null hypothesis be *that the use of stents has no effect on the risk of stroke*. That is, the proportion of patients that experience stroke in the treatment group equals the proportion of patients that experience stroke in the control group.

H_0: $p_1 = p_2$ (where p_1 denotes the treatment group and p_2 denotes the control group.)

Let the alternative hypothesis be that the use of stents *does have an effect on the risk of stroke*. That is, the proportion of patients that experience stroke in the treatment group is different from the proportion of patients that experience stroke in the control group.

H_A: $p_1 \neq p_2$ (where p_1 denotes the treatment group and p_2 denotes the control group.)

45 of 224 patients assigned to treatment group experienced stroke during the first 30 days of enrollment, while 28 of 227 patients assigned to control group experienced stroke during the same period of time. So $\hat{p}_1$ and $\hat{p}_2$ are:

$\hat{p}_1 = 45/224 = 20.1\%$ and $\hat{p}_2 = 28/227 = 12.3\%$.

Let $\alpha = 0.05$ for this hypothesis testing. The 95% confidence interval is

$$(\hat{p}_1 - \hat{p}_2) \pm z * \sqrt{\frac{\hat{p}_1 (1 - \hat{p}_1)}{n_1} + \frac{\hat{p}_2 (1 - \hat{p}_2)}{n_2}}$$

$$(0.201 - 0.123) \pm 1.96 * \sqrt{\frac{0.201 (0.799)}{224} + \frac{0.123 (0.877)}{227}}$$

$$= 0.078 \pm 0.068$$

$$= (0.01, 0.146)$$

The z-statistic value and the p-value are:

```
# sample proportion for both groups
p1_hat = treat_str_num/treat_total
p2_hat = cont_str_num/cont_total
p_hat = (treat_str_num+cont_str_num)/(treat_total+cont_total)
z_stat = (p1_hat-p2_hat)/(sqrt((p_hat*(1-p_hat)*((1/treat_total)+(1/cont_tota
l)))))
z_stat

## [1] 2.23548

p_value = 2*(1-pnorm(z_stat))
p_value

## [1] 0.02538586
```

At $\alpha = 0.05$, since the p-value is $< \alpha$, we reject the null hypothesis in favor of the alternative hypothesis. Again for the 0-365 days data, it can be said that the proportion of patients that experience stroke in the treatment group *is different* from the proportion of patients that experience stroke in the control group with 95% confidence.

Conclusion

While the doctors had expected that stents would help reduce the risk of stroke for at-risk patients, the data discussed here reveals compelling evidence that stents rather cause harm and increase the risk of stroke. Higher percentage of patients in the treatment group experienced stroke compared to the percentage of patients in the control group in both 30 days and 365 days data. One-sided hypothesis test would have been a great tool to show doctors' point if the data had shown that stents do help the patients, however, since the results had turned out the opposite way, two-sided hypothesis test was used instead to show that the use of stent *has an impact* on the risk of stroke.