Paolo Tenconi

# A statistical study of mammary vessel after breast cancer surgery

2004/14

UNIVERSITÀ DELL'INSUBRIA
FACOLTÀ DI ECONOMIA

http://eco.uninsubria.it

In questi quaderni vengono pubblicati i lavori dei docenti della Facoltà di Economia dell'Università dell'Insubria. La pubblicazione di contributi di altri studiosi, che abbiano un rapporto didattico o scientifico stabile con la Facoltà, può essere proposta da un professore della Facoltà, dopo che il contributo sia stato discusso pubblicamente. Il nome del proponente è riportato in nota all'articolo. I punti di vista espressi nei quaderni della Facoltà di Economia riflettono unicamente le opinioni degli autori, e non rispecchiano necessariamente quelli della Facoltà di Economia dell'Università dell'Insubria.

These Working papers collect the work of the Faculty of Economics of the University of Insubria. The publication of work by other Authors can be proposed by a member of the Faculty, provided that the paper has been presented in public. The name of the proposer is reported in a footnote. The views expressed in the Working papers reflect the opinions of the Authors only, and not necessarily the ones of the Economics Faculty of the University of Insubria.


Printed in Italy in May 2004
Università degli Studi dell'Insubria
Via Ravasi 2, 21100 Varese, Italy

# A statistical study of mammary vessel after breast cancer surgery

Paolo Tenconi *

*Dip. di Economia Università dell'Insubria, Via Ravasi 2, 21100 Varese, Italy.
Email: ptenconi@eco.uninsubria.it

# 1 Introduction and Main Conclusions

The following statistical study is about a series of quantitative response variables monitored three and six months after a breast operation. All patients that underwent a brest cancer operation from January 2003 untill June 2003 have been enrolled in the study.
The number of patients observed is 38, but we have excluded from this study a patient for wich we do not have observed all investigated variables.

The main issues involved here are:

- Descriptive analysis
- Temporal evolution of phenomena
- Effects of patient condition on the response variables

In the following the three and six months variations of the response variables are labeled as $\delta(3)$ and $\delta(6)$ respectively, while the three to six month variation is marked as $\delta(6) - \delta(3)$.

## 1.1 Response Variables

The response variables recorded are all quantitative and continuous in nature.
The resistence indicator, IR, is built as following:

$$IR = \frac{Maximum\ Artery\ Velocity - Minimum\ Artery\ Velocity}{Maximum\ Artery\ Velocity}$$

## 1.2 Explicative Variables

The covariates measured on each patient are all qualitative except for age: smoking habit (yes/no), kind of operation and hystological type of the tumor. Descriptive statistics are presented in Figure 1 and in Tables 1-5.
People are classified as smokers if they smoke, on average, more than 5 cigarettes each day.

| Min. | 1st Qu. | Median | Mean | 3rd Qu. | Max. |
|---|---|---|---|---|---|
| 30.0 | 49.0 | 55.0 | 54.7 | 63.0 | 79.0 |

Table 1: Age: Summary Statistics

| Categories | [30, 40) | [40,50) | [50,60) | [60,70) | [70,80) |
|---|---|---|---|---|---|
| Frequency | 6 | 7 | 12 | 10 | 2 |
| Density | 0.0162 | 0.0189 | 0.0324 | 0.0270 | 0.0060 |

Table 2: Age: Frequencies and densities

| Non Smokers | Smokers |
|---|---|
| 28 | 9 |

Table 3: Smoke: Absolute Frequencies

| Colloid | Papillary | Lobular | Intraductal | Ductal | Tubular |
|---|---|---|---|---|---|
| 1 | 1 | 7 | 2 | 25 | 1 |

Table 4: Hystological type: Absolute Frequencies

| Medial Quadr. | Lateral Quadr. | Central Quadr. | Mastectomy |
|---|---|---|---|
| 9 | 16 | 9 | 3 |

Table 5: Kind of operation: Absolute Frequencies

## 1.3 Temporal Evolution

Figures 2-3 show changes in distribution for the response variable by mean of boxplots. The typical pattern we encounter presents an increase/decrease of the level of the variable at three months, while levels similar to the initial ones are approximately recovered six months after the operation. Figures 4-5 stress the mean level (dots) changes with confidence bands at 90% level (bars) to detect the significance of any observed variation. We indicate with $x_i$ the $i$-th monitored value of variable $X$ and by $\overline{x}$ its average. We let $t^r_\alpha$ be $1-\alpha$ quantile of a Student-T distribution with $r$ degrees of freedom. Assuming that the data are approximately normaly distribuited the 90% confidence interval has this form:

$$x_{1,2} = \bar{x} \pm t^{37-1}_{0,1} \frac{\sum_{i=1}^{37}(x_i - \bar{x})^2/(37-1)}{\sqrt{37}}$$

The normality assumption has been checked by mean of the Kolmogorov-Smirnov Normality test, see Conover (1971). Based on the resulting p-values all above 0.05 we conclude that all variables can be assumed to follow a normal distribution.

## 1.4 Statistical methodology

The analysis has been conducted using the freeware software (R http://www.r-project.org/), an emulator of the commercial package S-Plus.
We used analysis of covariance to take into account patient age, while investigating differences among groups (smokers/non-smokers, kind of operation and histological types) for each monitored variable. We found no differences in mean level among groups at 5% significance level for any investigated variable. The results are reported in Section 3 for each one of the response variable serapately.

We also estimated a linear regression model for each one of the response variables using age as explanatory variable and constructing dummy variables for each one of the other qualitative covariates. None of the regressor is statistically significant at a 5% significance level.

## 1.5 Temporal variations

We found a significative evolution of means of almost all variables over time. The pattern we found in minimum artery flow (p-value= 0,1513%), maximum artery velocity (p-value= 1,885%), minimum artery velocity (p-value $\approx$ 0) shows an increase at 3 months after the operation, while after 6 months, on average, these variables return to pre-operation levels (minimum artery flow p-value= 38,28%, maximum artery velocity p-value= 16,71%, minimum artery velocity p-value=50,91%).

The other variables show different patterns among each other: artery diameter (p-value= 2,78%) and maximum artery flow (p-value= 4,395%) have a significant difference (descrease) six months after the operation, artery-IR after a decrease in its mean (p-value $\approx$ 0) has a recover not sufficient to reach its initial average level (p-value= 0,4468%), while vein diameter is the only variable that does not show any significant change in its mean level three (p-value=32,98%) and six (p-value=23,89%) months after the operation.

We therefore conclude that any prediction on the evolution of patients conditions (at least relative to the monitored parameters) after breast cancer operation should be conducted irrespectively to the patient smoking habit, to the kind of operation and the histological type of the tumor. On the other hand different patients show similar temporal behaviour relative to the response variable monitored. These similarities can help in predicting the evolution over time of new patients.

# 2 Graphics

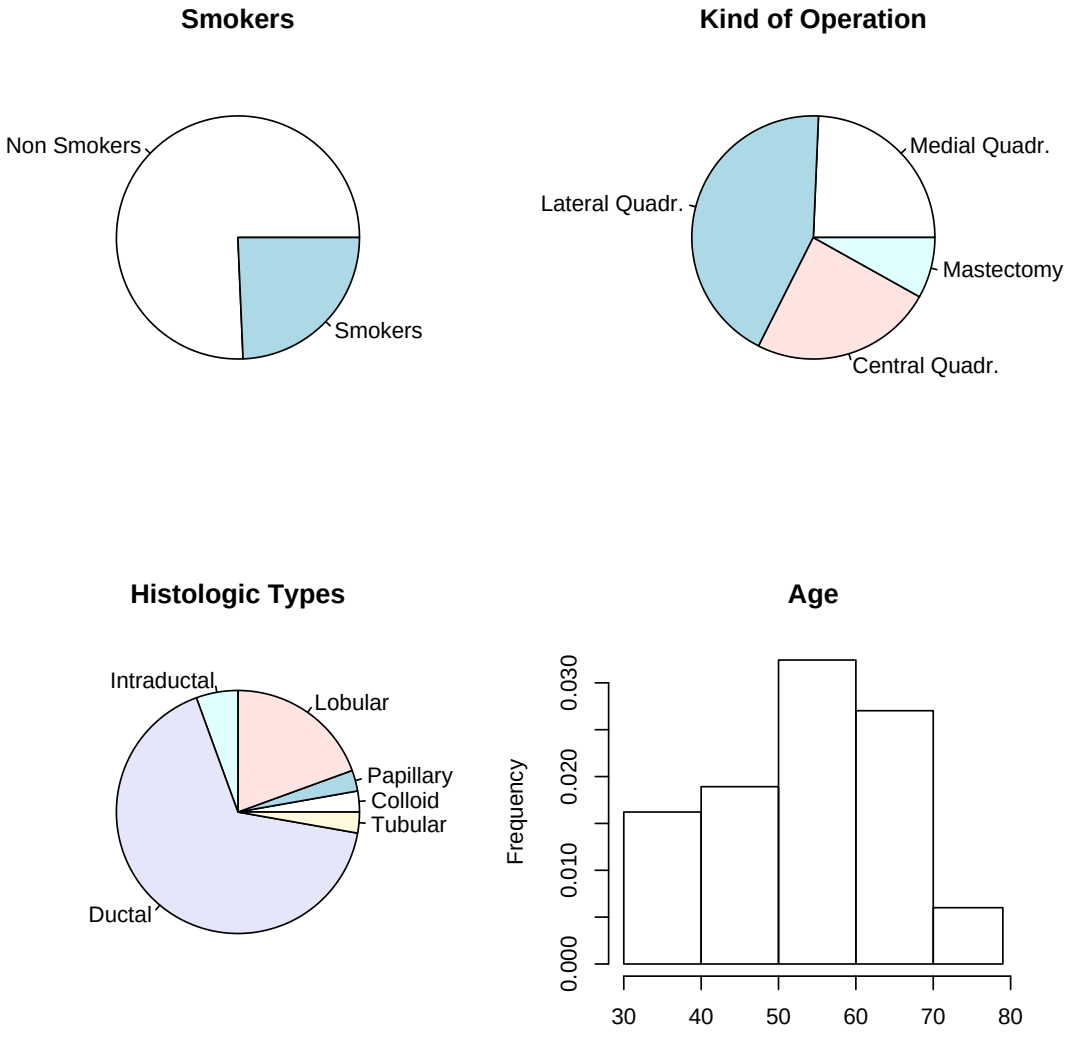


Figure 1: Explanatory Variables

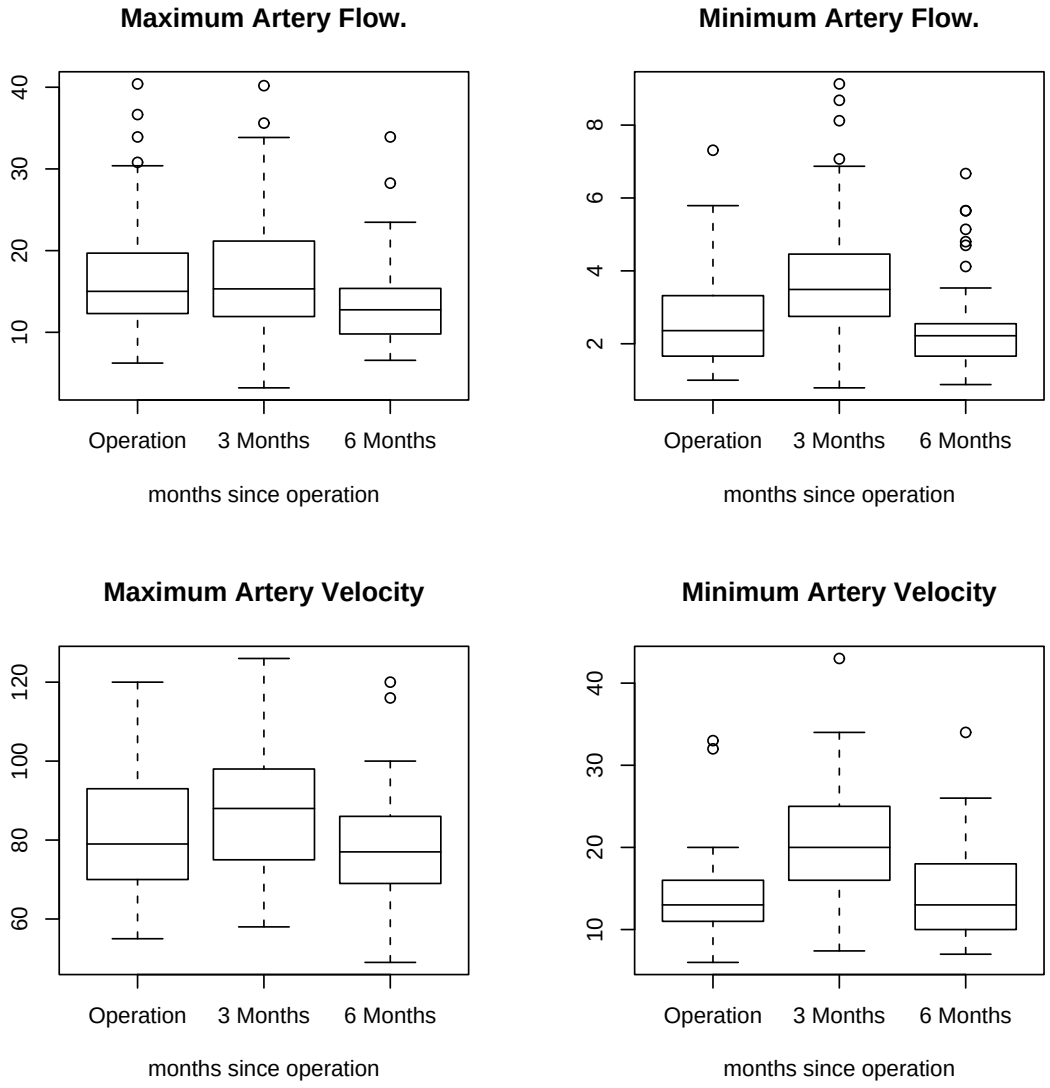


Figure 2: Response Variables Boxplot

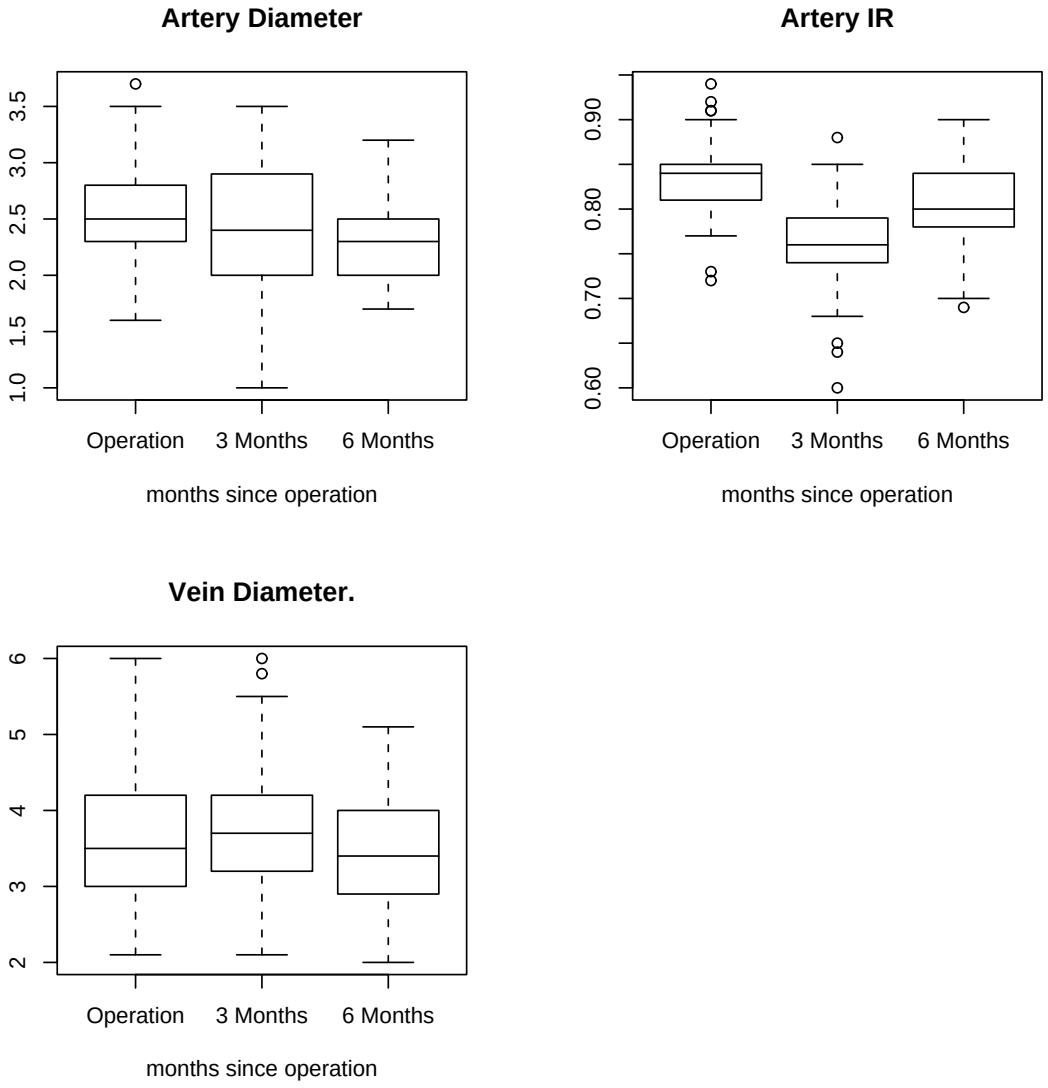


Figure 3: Response Variables Boxplot

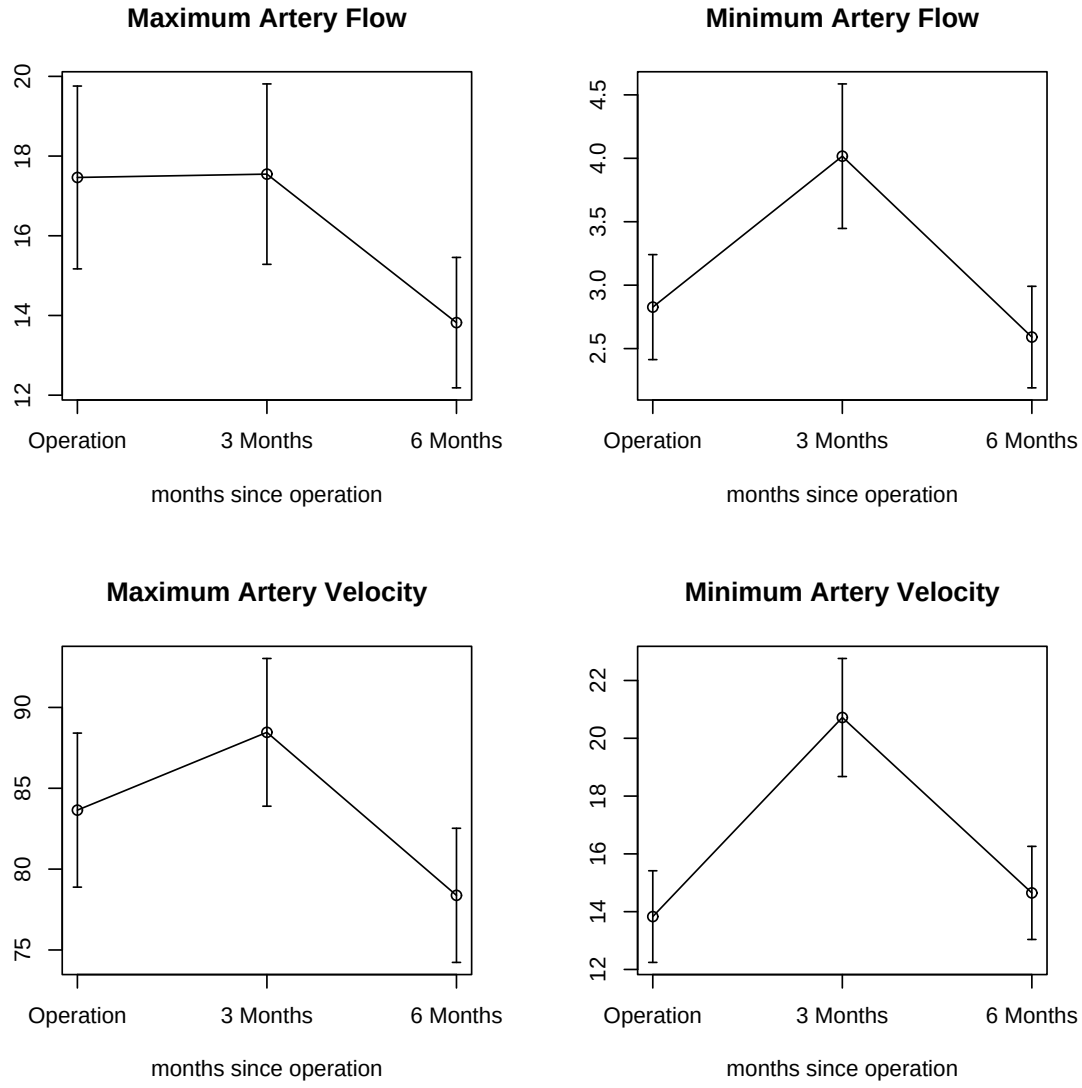


Figure 4: Temporal Means: $\bar{x} \pm t_{0,1}^{37-1} \frac{\sum_{i=1}^{37}(x_i-\bar{x})^2/(37-1)}{\sqrt{37}}$

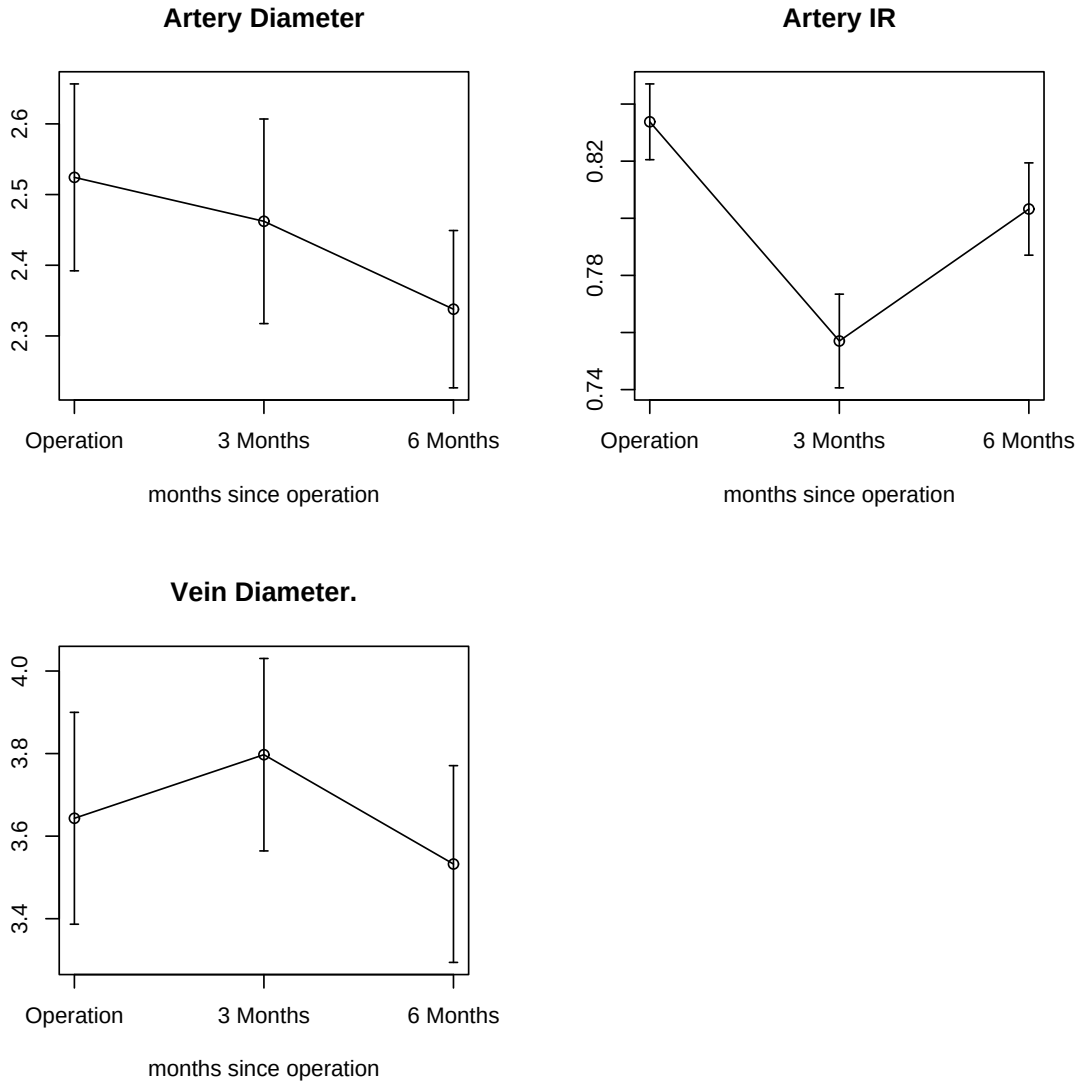


Figure 5: Temporal Means: $\bar{x} \pm t_{0,1}^{37-1} \frac{\sum_{i=1}^{37}(x_i-\bar{x})^2/(37-1)}{\sqrt{37}}$

# 3 Maximum Artery Flow

## 3.1 Maximum Artery Flow $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 3.4433 | 8.9823 | 0.38 | 0.7041 |
| age | −0.1323 | 0.1574 | −0.84 | 0.4071 |
| smoke | 2.3577 | 4.1119 | 0.57 | 0.5705 |
| Lateral Quadrantectomy | 5.4665 | 4.2377 | 1.29 | 0.2066 |
| Central Quadrantectomy | 3.6347 | 4.6842 | 0.78 | 0.4437 |
| Mastectomy | 0.6937 | 7.1230 | 0.10 | 0.9230 |

Table 6: Linear Model: Maximum Artery Flow $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 68.05 | 68.05 | 0.70 | 0.4106 |
| smoke | 1 | 43.92 | 43.92 | 0.45 | 0.5078 |
| kind of operation | 3 | 191.87 | 63.96 | 0.65 | 0.5866 |

Table 7: Ancova: Maximum Artery Flow $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1884 | 0.1446 |
| ttest | 0.053 | 0.958 |

Table 8: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 0.053 | 0.479 |

Table 9: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 3.2 Maximum Artery Flow $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 2.4486 | 7.7215 | 0.32 | 0.7533 |
| age | −0.1708 | 0.1353 | −1.26 | 0.2164 |
| smoke | 5.6678 | 3.5347 | 1.60 | 0.1190 |
| Lateral Quadrantectomy | 3.9103 | 3.6429 | 1.07 | 0.2914 |
| Central Quadrantectomy | 2.7054 | 4.0267 | 0.67 | 0.5066 |
| Mastectomy | −5.8998 | 6.1232 | −0.96 | 0.3427 |

Table 10: Linear Model: Maximum Artery Flow $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 191.24 | 191.24 | 2.65 | 0.1140 |
| smoke | 1 | 135.25 | 135.25 | 1.87 | 0.1812 |
| kind of operation | 3 | 276.69 | 92.23 | 1.28 | 0.2998 |

Table 11: Ancova: Maximum Artery Flow $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1963 | 0.1154 |
| ttest | -2.4932 | 0.01739 |

Table 12: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -2.4932 | 0.008697 |

Table 13: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 3.3 Maximum Artery Flow $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 1.7303 | 71.546 | 0.0879 |

Table 14: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 4 Minimum Artery Flow

## 4.1 Minimum Artery Flow $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 1.8635 | 2.1566 | 0.86 | 0.3942 |
| age | −0.0272 | 0.0378 | −0.72 | 0.4765 |
| smoke | 0.3470 | 0.9872 | 0.35 | 0.7276 |
| Lateral Quadrantectomy | 1.1837 | 1.0174 | 1.16 | 0.2535 |
| Central Quadrantectomy | 0.6862 | 1.1246 | 0.61 | 0.5462 |
| Mastectomy | 0.6531 | 1.7102 | 0.38 | 0.7052 |

Table 15: Linear Model: Minimum Artery Flow $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 2.25 | 2.25 | 0.40 | 0.5326 |
| smoke | 1 | 1.66 | 1.66 | 0.30 | 0.5908 |
| kind of operation | 3 | 7.76 | 2.59 | 0.46 | 0.7130 |

Table 16: Ancova: Minimum Artery Flow $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.0895 | 0.928 |
| ttest | 3.1798 | 0.003027 |

Table 17: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 3.1798 | 0.001513 |

Table 18: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 4.2 Minimum Artery Flow $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 0.2777 | 1.5168 | 0.18 | 0.8559 |
| age | −0.0168 | 0.0266 | −0.63 | 0.5325 |
| smoke | 0.9451 | 0.6944 | 1.36 | 0.1833 |
| Lateral Quadrantectomy | 0.3399 | 0.7156 | 0.47 | 0.6382 |
| Central Quadrantectomy | 0.1776 | 0.7910 | 0.22 | 0.8239 |
| Mastectomy | −0.1966 | 1.2028 | −0.16 | 0.8712 |

Table 19: Linear Model: Minimum Artery Flow $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 2.10 | 2.10 | 0.75 | 0.3927 |
| smoke | 1 | 5.52 | 5.52 | 1.98 | 0.1696 |
| kind of operation | 3 | 1.11 | 0.37 | 0.13 | 0.9397 |

Table 20: Ancova: Minimum Artery Flow $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1436 | 0.4302 |
| ttest | -0.8836 | 0.3828 |

Table 21: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -0.8836 | 0.1914 |

Table 22: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 4.3 Minimum Artery Flow $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 3.101 | 65.158 | 0.002849 |

Table 23: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 5 Maximum Artery Velocity

## 5.1 Maximum Artery Velocity $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 0.2141 | 0.2356 | 0.91 | 0.3705 |
| age | −0.0032 | 0.0041 | −0.78 | 0.4411 |
| smoke | 0.0677 | 0.1079 | 0.63 | 0.5348 |
| Lateral Quadrantectomy | 0.0242 | 0.1112 | 0.22 | 0.8294 |
| Central Quadrantectomy | 0.0652 | 0.1229 | 0.53 | 0.5994 |
| Mastectomy | 0.0915 | 0.1869 | 0.49 | 0.6280 |

Table 24: Linear Model: Maximum Artery Velocity $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.06 | 0.06 | 0.83 | 0.3693 |
| smoke | 1 | 0.05 | 0.05 | 0.70 | 0.4101 |
| kind of operation | 3 | 0.03 | 0.01 | 0.14 | 0.9336 |

Table 25: Ancova: Maximum Artery Velocity $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1362 | 0.4987 |
| ttest | 2.1576 | 0.03771 |

Table 26: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 2.1576 | 0.01885 |

Table 27: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 5.2 Maximum Artery Velocity $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 0.1417 | 0.2117 | 0.67 | 0.5082 |
| age | −0.0034 | 0.0037 | −0.92 | 0.3625 |
| smoke | 0.0608 | 0.0969 | 0.63 | 0.5350 |
| Lateral Quadrantectomy | −0.0101 | 0.0999 | −0.10 | 0.9205 |
| Central Quadrantectomy | 0.0003 | 0.1104 | 0.00 | 0.9980 |
| Mastectomy | −0.0049 | 0.1679 | −0.03 | 0.9769 |

Table 28: Linear Model: Maximum Artery Velocity $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.07 | 0.07 | 1.23 | 0.2752 |
| smoke | 1 | 0.02 | 0.02 | 0.43 | 0.5172 |
| kind of operation | 3 | 0.00 | 0.00 | 0.01 | 0.9995 |

Table 29: Ancova: Maximum Artery Velocity $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.0906 | 0.9218 |
| ttest | -0.979 | 0.3341 |

Table 30: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -0.979 | 0.1671 |

Table 31: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 5.3 Maximum Artery Velocity $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 2.2607 | 71.127 | 0.02684 |

Table 32: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 6 Minimum Artery Velocity

## 6.1 Minimum Artery Velocity $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 14.1328 | 6.7513 | 2.09 | 0.0446 |
| age | −0.1521 | 0.1183 | −1.29 | 0.2081 |
| smoke | 0.9453 | 3.0906 | 0.31 | 0.7618 |
| Lateral Quadrantectomy | 1.0657 | 3.1852 | 0.33 | 0.7402 |
| Central Quadrantectomy | −0.0219 | 3.5207 | −0.01 | 0.9951 |
| Mastectomy | 4.8271 | 5.3538 | 0.90 | 0.3742 |

Table 33: Linear Model: Minimum Artery Velocity $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 82.67 | 82.67 | 1.50 | 0.2305 |
| smoke | 1 | 25.93 | 25.93 | 0.47 | 0.4985 |
| kind of operation | 3 | 52.55 | 17.52 | 0.32 | 0.8129 |

Table 34: Ancova: Minimum Artery Velocity $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1139 | 0.7234 |
| ttest | 5.8079 | 1.255e-06 |

Table 35: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 5.8079 | 6.276e-07 |

Table 36: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 6.2 Minimum Artery Velocity $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 4.5565 | 7.1109 | 0.64 | 0.5264 |
| age | −0.0538 | 0.1246 | −0.43 | 0.6687 |
| smoke | 0.6471 | 3.2552 | 0.20 | 0.8437 |
| Lateral Quadrantectomy | −1.6041 | 3.3548 | −0.48 | 0.6359 |
| Central Quadrantectomy | −2.2223 | 3.7083 | −0.60 | 0.5533 |
| Mastectomy | 3.5037 | 5.6390 | 0.62 | 0.5389 |

Table 37: Linear Model: Minimum Artery Velocity $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 10.45 | 10.45 | 0.17 | 0.6825 |
| smoke | 1 | 12.90 | 12.90 | 0.21 | 0.6496 |
| kind of operation | 3 | 84.96 | 28.32 | 0.46 | 0.7108 |

Table 38: Ancova: Minimum Artery Velocity $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1876 | 0.1479 |
| ttest | 0.6669 | 0.5091 |

Table 39: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 0.6669 | 0.2546 |

Table 40: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 6.3 Minimum Artery Velocity $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 3.5554 | 71.914 | 0.000672 |

Table 41: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 7 Artery Diameter

## 7.1 Artery Diameter $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 0.0109 | 0.5991 | 0.02 | 0.9856 |
| age | −0.0049 | 0.0105 | −0.47 | 0.6448 |
| smoke | 0.1037 | 0.2742 | 0.38 | 0.7079 |
| Lateral Quadrantectomy | 0.3090 | 0.2826 | 1.09 | 0.2827 |
| Central Quadrantectomy | 0.1435 | 0.3124 | 0.46 | 0.6492 |
| Mastectomy | 0.0067 | 0.4751 | 0.01 | 0.9889 |

Table 42: Linear Model: Artery Diameter $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.07 | 0.07 | 0.16 | 0.6884 |
| smoke | 1 | 0.08 | 0.08 | 0.19 | 0.6638 |
| kind of operation | 3 | 0.64 | 0.21 | 0.49 | 0.6891 |

Table 43: Ancova: Artery Diameter $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1069 | 0.7919 |
| ttest | -0.6002 | 0.5521 |

Table 44: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -0.6002 | 0.2761 |

Table 45: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 7.2 Artery Diameter $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | −0.1022 | 0.5146 | −0.20 | 0.8439 |
| age | −0.0052 | 0.0090 | −0.57 | 0.5712 |
| smoke | 0.3507 | 0.2355 | 1.49 | 0.1466 |
| Lateral Quadrantectomy | 0.2571 | 0.2428 | 1.06 | 0.2977 |
| Central Quadrantectomy | 0.1271 | 0.2683 | 0.47 | 0.6390 |
| Mastectomy | −0.3621 | 0.4080 | −0.89 | 0.3817 |

Table 46: Linear Model: Artery Diameter $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.23 | 0.23 | 0.71 | 0.4068 |
| smoke | 1 | 0.53 | 0.53 | 1.65 | 0.2082 |
| kind of operation | 3 | 1.10 | 0.37 | 1.14 | 0.3492 |

Table 47: Ancova: Artery Diameter $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1142 | 0.7206 |
| ttest | -1.9811 | 0.05526 |

Table 48: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -1.9811 | 0.02763 |

Table 49: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 7.3 Artery Diameter $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 0.8883 | 71.353 | 0.3774 |

Table 50: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 8 Artery IR

## 8.1 Artery IR $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | −0.1262 | 0.0574 | −2.20 | 0.0355 |
| age | 0.0012 | 0.0010 | 1.22 | 0.2324 |
| smoke | 0.0086 | 0.0263 | 0.33 | 0.7464 |
| Lateral Quadrantectomy | −0.0292 | 0.0271 | −1.08 | 0.2900 |
| Central Quadrantectomy | −0.0153 | 0.0299 | −0.51 | 0.6139 |
| Mastectomy | −0.0414 | 0.0455 | −0.91 | 0.3701 |

Table 51: Linear Model: Artery IR $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.00 | 0.00 | 0.94 | 0.3403 |
| smoke | 1 | 0.00 | 0.00 | 0.00 | 0.9854 |
| kind of operation | 3 | 0.01 | 0.00 | 0.48 | 0.7010 |

Table 52: Ancova: Artery IR $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.0943 | 0.8975 |
| ttest | -7.6696 | 4.433e-09 |

Table 53: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -7.6696 | 2.217e-09 |

Table 54: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 8.2 Artery IR $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | −0.0477 | 0.0630 | −0.76 | 0.4547 |
| age | 0.0005 | 0.0011 | 0.48 | 0.6311 |
| smoke | −0.0028 | 0.0289 | −0.10 | 0.9242 |
| Lateral Quadrantectomy | −0.0094 | 0.0297 | −0.32 | 0.7529 |
| Central Quadrantectomy | −0.0063 | 0.0329 | −0.19 | 0.8493 |
| Mastectomy | −0.0719 | 0.0500 | −1.44 | 0.1606 |

Table 55: Linear Model: Artery IR $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.00 | 0.00 | 0.09 | 0.7604 |
| smoke | 1 | 0.00 | 0.00 | 0.42 | 0.5210 |
| kind of operation | 3 | 0.01 | 0.00 | 0.74 | 0.5339 |

Table 56: Ancova: Artery IR $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.0957 | 0.8867 |
| ttest | -2.7643 | 0.008937 |

Table 57: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -2.7643 | 0.004468 |

Table 58: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 8.3 Artery IR. $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | -3.1003 | 71.307 | 0.002768 |

Table 59: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# 9 Vein Diameter

## 9.1 Vein Diameter $\delta(3)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | −0.2248 | 0.8885 | −0.25 | 0.8019 |
| age | 0.0061 | 0.0156 | 0.39 | 0.6985 |
| smoke | −0.5442 | 0.4067 | −1.34 | 0.1906 |
| Lateral Quadrantectomy | 0.2782 | 0.4192 | 0.66 | 0.5117 |
| Central Quadrantectomy | 0.0611 | 0.4633 | 0.13 | 0.8959 |
| Mastectomy | 0.5304 | 0.7046 | 0.75 | 0.4572 |

Table 60: Linear Model: Vein Diameter $\delta(3)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.71 | 0.71 | 0.74 | 0.3949 |
| smoke | 1 | 1.20 | 1.20 | 1.26 | 0.2705 |
| kind of operation | 3 | 0.81 | 0.27 | 0.28 | 0.8389 |

Table 61: Ancova: Vein Diameter $\delta(3)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.1403 | 0.4599 |
| ttest | 0.9879 | 0.3298 |

Table 62: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | 0.9879 | 0.1649 |

Table 63: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} > 0$

## 9.2 Vein Diameter $\delta(6)$

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | −0.2135 | 0.8896 | −0.24 | 0.8119 |
| age | −0.0078 | 0.0156 | −0.50 | 0.6206 |
| smoke | −0.0066 | 0.4072 | −0.02 | 0.9872 |
| Lateral Quadrantectomy | 0.8508 | 0.4197 | 2.03 | 0.0513 |
| Central Quadrantectomy | 0.4554 | 0.4639 | 0.98 | 0.3339 |
| Mastectomy | 0.6419 | 0.7054 | 0.91 | 0.3699 |

Table 64: Linear Model: Vein Diameter $\delta(6)$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| age | 1 | 0.02 | 0.02 | 0.02 | 0.8843 |
| smoke | 1 | 0.13 | 0.13 | 0.14 | 0.7131 |
| kind of operation | 3 | 3.98 | 1.33 | 1.38 | 0.2663 |

Table 65: Ancova: Vein Diameter $\delta(6)$

| | stat. value | p-value |
|---|---|---|
| Normality test | 0.112 | 0.742 |
| ttest | -0.6948 | 0.4916 |

Table 66: KS normality test and $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

| | stat. value | p-value |
|---|---|---|
| ttest | -0.6948 | 0.2458 |

Table 67: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} < 0$

## 9.3 Vein Diameter $\delta(6) - \delta(3)$

| | df | T | p-value |
|---|---|---|---|
| ttest | 1.1875 | 71.964 | 0.2389 |

Table 68: Test $H_0 : \bar{x} = 0$ $H_1 : \bar{x} \neq 0$

# References

William J. Conover (1971), Practical nonparametric statistics. *New York: John Wiley & Sons*, pp. 295-301, pp. 309-314

Table 69: Correlation Matrix

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max Artery Flow $\delta(3)$ | 1.00 | 0.75 | 0.90 | 0.63 | 0.39 | 0.39 | 0.28 | 0.08 | 0.86 | 0.59 | 0.04 | 0.05 | 0.11 | 0.32 |
| Max Artery Flow $\delta(6)$ | 0.75 | 1.00 | 0.60 | 0.78 | 0.27 | 0.40 | 0.15 | −0.00 | 0.61 | 0.84 | 0.01 | 0.01 | 0.01 | 0.32 |
| Min Artery Flow $\delta(3)$ | 0.90 | 0.60 | 1.00 | 0.63 | 0.29 | 0.27 | 0.56 | 0.20 | 0.80 | 0.50 | −0.20 | −0.16 | 0.23 | 0.33 |
| Min Artery Flow $\delta(6)$ | 0.63 | 0.78 | 0.63 | 1.00 | 0.22 | 0.42 | 0.30 | 0.51 | 0.56 | 0.65 | −0.07 | −0.49 | −0.04 | 0.16 |
| Max Artery Velocity $\delta(3)$ | 0.39 | 0.27 | 0.29 | 0.22 | 1.00 | 0.73 | 0.52 | 0.40 | −0.07 | −0.12 | −0.00 | −0.14 | −0.13 | 0.00 |
| Max Artery Velocity $\delta(6)$ | 0.39 | 0.40 | 0.27 | 0.42 | 0.73 | 1.00 | 0.34 | 0.60 | 0.07 | −0.09 | 0.06 | −0.16 | −0.07 | 0.04 |
| Min Artery Velocity $\delta(3)$ | 0.28 | 0.15 | 0.56 | 0.30 | 0.52 | 0.34 | 1.00 | 0.48 | 0.02 | −0.06 | −0.62 | −0.46 | 0.10 | 0.13 |
| Min Artery Velocity $\delta(6)$ | 0.08 | −0.00 | 0.20 | 0.51 | 0.40 | 0.60 | 0.48 | 1.00 | −0.07 | −0.29 | −0.21 | −0.77 | −0.13 | −0.15 |
| Artery Diameter $\delta(3)$ | 0.86 | 0.61 | 0.80 | 0.56 | −0.07 | 0.07 | 0.02 | −0.07 | 1.00 | 0.67 | 0.10 | 0.10 | 0.18 | 0.29 |
| Artery Diameter $\delta(6)$ | 0.59 | 0.84 | 0.50 | 0.65 | −0.12 | −0.09 | −0.06 | −0.29 | 0.67 | 1.00 | 0.08 | 0.08 | 0.03 | 0.27 |
| Artery IR $\delta(3)$ | 0.04 | 0.01 | −0.20 | −0.07 | −0.00 | 0.06 | −0.62 | −0.21 | 0.10 | 0.08 | 1.00 | 0.39 | −0.01 | −0.08 |
| Artery IR $\delta(6)$ | 0.05 | 0.01 | −0.16 | −0.49 | −0.14 | −0.16 | −0.46 | −0.77 | 0.10 | 0.08 | 0.39 | 1.00 | 0.16 | 0.09 |
| Vein Diameter $\delta(3)$ | 0.11 | 0.01 | 0.23 | −0.04 | −0.13 | −0.07 | 0.10 | −0.13 | 0.18 | 0.03 | −0.01 | 0.16 | 1.00 | 0.66 |
| Vein Diameter $\delta(6)$ | 0.32 | 0.32 | 0.33 | 0.16 | 0.00 | 0.04 | 0.13 | −0.15 | 0.29 | 0.27 | −0.08 | 0.09 | 0.66 | 1.00 |