Eleanor Cotton

BIOS 6623-Project Two

**Introduction**

The primary aim of this research project is to calculate the predicted 30 day mortality rate (as well as a measure of variation in this estimate) of heart surgery patients at 44 different VA hospitals. The VA does a review of hospitals every six months in order to identify hospitals that have an unexpectedly high or low mortality rate for these patients. It is important to compare each hospital’s observed mortality rate to their predicted rate, which can account for the overall health of the population of patients.

Secondary aims of this project are to investigate the relationship between albumin and death rate, to see if it is a measurement that should be used in the estimation of predicted death rates.

The data used for analysis contains 26520 individuals who had either valve or CABG heart surgery from 44 different veterans’ hospitals. Data from the current six month time period (period 39) was available, as well as data from the past five six month periods. Comorbidities (BMI, ASA score, albumin levels) were recorded for each patient, along with their 30 day mortality.

**Methods**

RStudio version 3.4.2 was used for all statistical analysis

The initial dataset contained 26520 individuals. Two people in that cohort did not have the valve or CABG heart surgery, so they were removed from the study. For modeling purposes, only those individuals with complete cases (those with BMI, ASA, and Procedure Type recorded) could be used, which was a cohort of 21346. Those missing covariate data other than albumin had similar mortality rates to those not missing any covariate data (3.2% and 3.7% respectively). Therefore, very minimal bias was introduced by using complete cases to generate our model.

The predicted death rate for period 39 was calculated on the 3478 individuals from period 39 who had complete cases. Hospital 30 did not have any complete cases for period 39, which made it impossible to find an expected death rate. Observed mortality rate was measured using data the 4424 individuals in period 39. Those missing covariate data other than albumin in period 39 also have similar mortality rates to those not missing any covariate data (3.0% and 3.4% respectively). Therefore, very minimal bias was introduced by comparing observed and predicted death rates.

Weight was measured in kilograms instead of pounds by hospitals 1 through 16 during period 39. These values were converted to pounds and BMI was recalculated for all individuals using the corrected weight values and height. Due to small sample sizes, ASA scores were recategorized into two groups: Low ASA (those with an original score of one, two, or three) and High ASA (those with an original score of four or five).

Near 62% of the cohort was missing albumin. Because of this, it was not used in the primary model. Albumin also appeared to be missing based on ASA score (MAR). Those who were not missing albumin only had high ASA scores (four or five). Those who were missing albumin had low and high ASA scores. It appears that albumin levels were only collected on individuals in general who were sicker.

Categorical data was presented using percents and group sizes. Numerical variables were presented using means and standard deviations.

Logistic regression was performed with 30 day mortality as the outcome, and BMI, ASA, and procedure type used as covariates (model 1). From this model, estimates of the expected mortality rate for each individual in period 39 were calculated. These estimates were then averaged across hospitals in order to get an expected death rate for each hospital. Observed mortality rate was calculated by divided the number of deaths at each hospital during period 39 by the number of total patients for that hospital.

A secondary logistic regression model was ran, again using 30 day mortality as the outcome, with BMI, procedure type and albumin as the covariates (model 2). Since every individual who had albumin level recorded had a high ASA score, it could not be included in the model.

Bootstrapping was performed in order to get an estimate of the variation associated with each death rate. Each bootstrap sample (samples = 10,000) was drawn from the complete cases dataset (n = 21346). This new sample was used to generate a new logistic regression model. The coefficients from this regression were then applied to the original dataset, and a new estimate of each hospital’s mortality rate was calculated based on the period 39 individuals. The 2.5 and 97.5 percentiles for each hospital from their 10,000 estimates could be found, giving a 95% confidence interval around the predicted mortality rate.

**Results**

Table One contains summary statistics of the variables of interest for all individuals (all periods), individuals from the most recent six month period (current period), as well as for the last five six month periods (past periods). The CABG surgery was the most commonly performed heart surgery for all periods (75.90%). The majority of patients for all periods had high ASA scores (69.42%). The average BMI for all periods was 28.61. The average albumin for all periods was 3.89. The 30 day mortality was 3.27% for all periods.

The 30 day mortality rate information for each hospital for period 39 is shown in table two. 1.15% of the patients from hospital one died during 30 days after their surgery. The predicted 30 day mortality rate for hospital one is 3.22%. The 95% CI for the predicted mortality rate for hospital one is 2.98 to 3.47. The ratio of observed mortality rate over predicted mortality rate (rounded to two decimal places in table 2) demonstrates how closely the observed and predicted mortality rates are. A value close to 1 means that the observed and predicted rates are very similar. A value greater than 1 means that the hospital has a higher observed mortality rate than predicted. A value less than one means that the hospital has a lower observed mortality rate than predicted. The final column groups the ratio into 3 groupings: ≤ 0.80 (hospitals that should be investigated because they have a lower mortality than predicted), 0.8-1.2 (hospitals that have similar observed and predicted mortality rates), and ≥ 1.20 (hospitals that should be investigated because they have a higher mortality rate than predicted). Graph 1 plots the observed/predicted mortality rate ratio for each hospital. Any hospital above the red line should be investigated due to a higher than expected mortality rate. Any hospital below the blue line should be investigated due a lower than expected mortality rate.

Table three shows the model coefficients for model 1 (used in prediction of death rates) and model 2 (the model with albumin as a predictor). Based on model 2 results, it does not appear that albumin is a significant predictor (p = 0.193), when controlling for BMI and procedure type.

**Conclusions**

Overall, there are 16 hospitals that have a much higher observed mortality rate than predicted (≥ 1.20). Most notable, hospitals 7, 17, 23, 31, 34 have the highest ratio of observed/predicted mortality rate ratios, with the observed mortality being twice as high as the predicted. These hospitals in particular should be investigated to see what they are doing that is worsening their mortality rates, but all 16 had an observed mortality rate that was at least 20% higher than predicted and should be investigated. There are 23 hospitals that have a much lower observed mortality rate than predicted. Most notable, hospital 19,32,33,42, and 44 have the lowest ratio of observation over predicted mortality rates. Each of these hospitals had an observed mortality rate of zero. These hospitals in particular should be investigated to see how they are improving their mortality rates, but all 23 hospitals had an observed rate that was at least 20% lower than expected and should be investigated. There are only 4 hospitals that have very similar observed and predicted mortality rates.

40 of the 44 hospitals should be investigated with the given cut offs (20% difference between observed and expected). The VA could consider changing the criteria of when they should investigate hospitals that are doing well. If the VA only investigated hospitals who had a 30% decrease in mortality rate, it would reduce the number of “good hospitals” (hospitals with better mortality rates) that need to be investigated from 23 to 13. This would help lessen the work required from the VA by only visiting the hospitals that are doing exceptionally well.

Albumin did not have a significant association with mortality rate, when controlling for procedure type and BMI. With the current data, we were not able to see if albumin added anything to a model, in addition to procedure type, BMI, and ASA. The collected albumin levels were only collected on individuals with high ASA scores, so ASA could not be included in the analysis model with albumin. We are unable to conjecture on the relationship of albumin and mortality rate, when controlling for procedure type, BMI, and ASA.

The study has several limitations. First, the observed mortality rate for each hospital is based on every patient in the study during period 39 (n = 4424). The predicted mortality rate for each hospital is based on only patients in the study during period 39 who were complete cases (n =3478). The complete cases cohort had a slightly higher mortality rate than the incomplete cases cohort (3.4% and 3.0% respectively). This could create a small bias in our predicted mortality rate by overestimating it, since it is using a sample of individuals with a higher mortality rate. Second, Hospital 30 had no complete cases during period 39, so it’s predicted mortality rate could not be calculated. The observed mortality rate is the only value we are able to use to see how hospital 30 is performing. We would recommend that hospital 30 is investigated nonetheless, since it has one of the highest observed mortality rate. Finally, ASA score had to be dichotomized due to small sample sizes, which results in a loss of information.

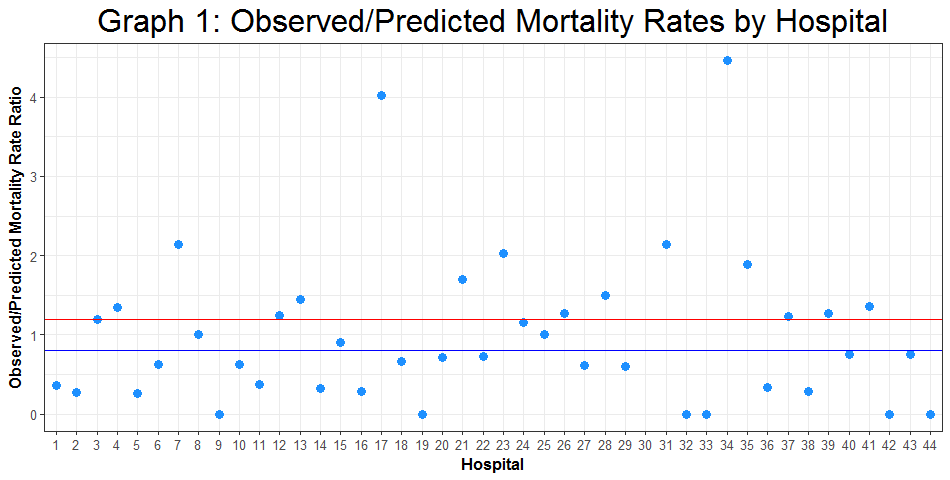
**Tables and Graphs**

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| **Table One: Comorbidities** | | | |
| **Variable** | **All Periods** | **Current Period** | **Past Periods** |
| **N** | 26518 | 4424 | 22094 |
| **Procedure**\* |  |  |  |
| Valve Surgery | 18.42 (4884) | 17.90 (792) | 18.52 (4092) |
| CABG Surgery | 75.90 (20126) | 76.40 (3380) | 75.79 (16746) |
| Missing | 5.69 (1508) | 5.70 (252) | 5.68 (1256) |
| **ASA**\* |  |  |  |
| Low (1,2,3) | 22.44 (5950) | 22.81 (1009) | 22.36 (4941) |
| High (4 or 5) | 69.42 (18408) | 69.60 (3079) | 69.38 (15329) |
| Missing | 8.15 (2160) | 7.59 (336) | 8.26 (1824) |
| **Weight**+ | 174.84 ± 26.91 (Missing = 1855) | 174.86 ± 27.37 (Missing = 418) | 174.84 ± 26.83 (Missing = 1437) |
| **Height**+ | 65.49 ± 2.56 (Missing = 1855) | 65.52 ± 2.61 (Missing = 418) | 65.48 ± 2.54 (Missing = 1437) |
| **BMI**+ | 28.61 ± 3.8 (Missing = 1855) | 28.58 ± 3.83 (Missing = 418) | 28.62 ± 3.79 (Missing = 1437) |
| **Albumin**+ | 3.89 ± 0.5 (Missing = 16496) | 3.89 ± 0.50 (Missing = 2695) | 3.9 ± 0.49 (Missing = 13801) |
| **30 day mortality**\* | 3.27 (868) | 3.28 (145) | 3.27 (723) |

\*Variables are described using % (n)

+Variables are described using mean ± sd

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Table Two: Mortality Rates by Hospital | | | | | | | |
| Hospital | **Number**  **Died** | **Number**  **Seen** | **Observed**  **Mort. Rate** | **Predicted**  **Mort. Rate** | **95% CI of**  **Pre. Mort. Rate** | **Obs./Pre.**  **Mort. Rate** | **High or Low**  **Ratio?** |
| 1 | 1 | 87 | 1.15 | 3.22 | (2.98, 3.47) | 0.36 | ≤ 0.80 |
| 2 | 1 | 106 | 0.94 | 3.43 | (3.17, 3.7) | 0.27 | ≤ 0.80 |
| 3 | 4 | 100 | 4.00 | 3.34 | (3.1, 3.60) | 1.20 | ≥ 1.20 |
| 4 | 4 | 94 | 4.26 | 3.17 | (2.94, 3.41) | 1.34 | ≥ 1.20 |
| 5 | 1 | 115 | 0.87 | 3.35 | (3.11, 3.61) | 0.26 | ≤ 0.80 |
| 6 | 2 | 104 | 1.92 | 3.07 | (2.85, 3.30) | 0.63 | ≤ 0.80 |
| 7 | 7 | 105 | 6.67 | 3.12 | (2.89, 3.35) | 2.14 | ≥ 1.20 |
| 8 | 4 | 120 | 3.33 | 3.34 | (3.09, 3.59) | 1.00 | 0.8-1.2 |
| 9 | 0 | 105 | 0 | 3.17 | (2.94, 3.41) | 0 | ≤ 0.80 |
| 10 | 2 | 100 | 2.00 | 3.15 | (2.92, 3.39) | 0.63 | ≤ 0.80 |
| 11 | 1 | 90 | 1.11 | 3.04 | (2.81, 3.28) | 0.37 | ≤ 0.80 |
| 12 | 4 | 98 | 4.08 | 3.28 | (3.04, 3.53) | 1.24 | ≥ 1.20 |
| 13 | 4 | 84 | 4.76 | 3.28 | (3.04, 3.54) | 1.45 | ≥ 1.20 |
| 14 | 1 | 103 | 0.97 | 3.00 | (2.77, 3.23) | 0.32 | ≤ 0.80 |
| 15 | 3 | 105 | 2.86 | 3.17 | (2.94, 3.41) | 0.90 | 0.8-1.2 |
| 16 | 1 | 111 | 0.90 | 3.13 | (2.90, 3.38) | 0.29 | ≤ 0.80 |
| 17 | 13 | 93 | 13.98 | 3.48 | (3.22, 3.75) | 4.02 | ≥ 1.20 |
| 18 | 2 | 95 | 2.11 | 3.18 | (2.94, 3.42) | 0.66 | ≤ 0.80 |
| 19 | 0 | 113 | 0 | 3.13 | (2.89, 3.37) | 0 | ≤ 0.80 |
| 20 | 2 | 98 | 2.04 | 2.84 | (2.62, 3.06) | 0.72 | ≤ 0.80 |
| 21 | 5 | 92 | 5.43 | 3.20 | (2.96, 3.44) | 1.70 | ≥ 1.20 |
| 22 | 2 | 86 | 2.33 | 3.21 | (2.98, 3.45) | 0.73 | ≤ 0.80 |
| 23 | 6 | 97 | 6.19 | 3.05 | (2.83, 3.29) | 2.03 | ≥ 1.20 |
| 24 | 4 | 104 | 3.85 | 3.33 | (3.09, 3.59) | 1.16 | 0.8-1.2 |
| 25 | 3 | 95 | 3.16 | 3.16 | (2.93, 3.40) | 1.00 | 0.8-1.2 |
| 26 | 4 | 99 | 4.04 | 3.18 | (2.95, 3.42) | 1.27 | ≥ 1.20 |
| 27 | 2 | 99 | 2.02 | 3.26 | (3.02, 3.51) | 0.62 | ≤ 0.80 |
| 28 | 5 | 101 | 4.95 | 3.30 | (3.05, 3.55) | 1.50 | ≥ 1.20 |
| 29 | 2 | 105 | 1.90 | 3.16 | (2.92, 3.40) | 0.60 | ≤ 0.80 |
| 30 | 10 | 117 | 8.55 | NA | NA | NA | NA |
| 31 | 7 | 104 | 6.73 | 3.15 | (2.91, 3.39) | 2.14 | ≥ 1.20 |
| 32 | 0 | 93 | 0 | 3.19 | (2.96, 3.43) | 0 | ≤ 0.80 |
| 33 | 0 | 113 | 0 | 3.29 | (3.05, 3.54) | 0 | ≤ 0.80 |
| 34 | 14 | 99 | 14.14 | 3.17 | (2.93, 3.41) | 4.46 | ≥ 1.20 |
| 35 | 5 | 84 | 5.95 | 3.14 | (2.91, 3.38) | 1.89 | ≥ 1.20 |
| 36 | 1 | 99 | 1.01 | 2.98 | (2.74, 3.22) | 0.34 | ≤ 0.80 |
| 37 | 4 | 107 | 3.74 | 3.05 | (2.83, 3.29) | 1.23 | ≥ 1.20 |
| 38 | 1 | 113 | 0.88 | 3.02 | (2.79, 3.25) | 0.29 | ≤ 0.80 |
| 39 | 4 | 101 | 3.96 | 3.13 | (2.90, 3.37) | 1.27 | ≥ 1.20 |
| 40 | 2 | 86 | 2.33 | 3.12 | (2.89, 3.36) | 0.75 | ≤ 0.80 |
| 41 | 5 | 116 | 4.31 | 3.18 | (2.95, 3.43) | 1.36 | ≥ 1.20 |
| 42 | 0 | 107 | 0 | 2.97 | (2.74, 3.20) | 0 | ≤ 0.80 |
| 43 | 2 | 83 | 2.41 | 3.22 | (2.98, 3.46) | 0.75 | ≤ 0.80 |
| 44 | 0 | 98 | 0 | 3.20 | (2.97, 3.44) | 0 | ≤ 0.80 |



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| **Table Three: Model Outcomes** | | | |
|  | **Coeff. Estimates** | **SE** | **P-value** |
| **Model 1** |  |  |  |
| Intercept | -4.832 | 0.326 | <0.0001 |
| ASA | 1.007 | 0.126 | <0.0001 |
| BMI | 0.011 | 0.011 | 0.315 |
| Procedure Type | 0.334 | 0.109 | 0.002 |
| **Model 2** |  |  |  |
| Intercept | -2.730 | 0.652 | <0.0001 |
| Albumin | -0.147 | 0.113 | 0.193 |
| BMI | -0.003 | 0.016 | 0.874 |
| Procedure Type | 0.191 | 0.150 | 0.204 |

**GitHub Link**

Full Code to generate the above analysis can be found at:

https://github.com/BIOS6623-UCD/bios6623-elcotton