Temporal Patterns in Surgical Patient Outcomes

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Introduction

Context and Background

Since the rise of the coronavirus disease (COVID-19), there has been a surge in the concern of a complication in healthcare industries worldwide. The shortage of healthcare professionals has been an increasingly discussed topic among citizens and healthcare providers alike as millions of people experienced the threat of a global pandemic. In general, the scarcity of medical industry professionals has led to a decline in the quality and availability of care in hospitals. (Džakula and Danko, 2022) It is widely known and studied that insufficient amounts of sleep and extended work shifts risk negative impacts on one's cognitive and motor performance. (Alhola and Päivi, 2007)Due to the risk of underperformance of healthcare workers, particularly surgeons, there has been a push to limit resident work hours to mitigate potential errors that may impact patients.

Given that the healthcare sector is one of high stakes that often demands medical professionals to work extensive shifts due to short staff and increased patient attendance, the risk of long work hours cannot be ignored. Furthermore, just as extended hours of work may lead to fatigue and a compromise in cognitive and physical tasks, typical workweek progression may lead to similar results. (Sessler et al., 2011) This study aims to address the association between multiple time-related factors and the resulting outcome of patients' operation cases.

These are the four main objectives of this case study (Sessler et al., 2011):

1) Is there any association between whether or not a patient's operation results in in-hospital complications and the day of the week in which an operation occurs?

2) Is there any association between whether or not a patient's operation results in 30-day mortality and the day of the week in which an operation occurs?

3) Is there any association between whether or not a patient's operation results in in-hospital complications and the time of day in which an operation occurs?

4) Is there any association between whether or not a patient's operation results in 30-day mortality and the time of day in which an operation occurs?

Answering these four questions will help healthcare industry leaders better understand the possible critical risks of progression in time from morning to evening as well as progression days of the week from Monday to Friday of surgeons on patient operation outcomes, particularly mortality and complication risks.

The Data

The data for this study was collected and provided by the Cleveland Clinic Lerner Research Institute. The data is formatted as patient-level observations that comprise 32,001 surgical patients from the Cleveland Clinic between January 2005 and September 2010. The data collection window consisted of the hours of 6 am to 7 pm during the work weekdays. Variables in the dataset include the patient's age, gender, race, ASA physical status, body mass index, United States Agency for Healthcare Research and Quality's Clinical Classifications Software (AHRQ-CCS) Procedure Category, Charlson Comorbidity Index, 30-Day Mortality Risk Stratification Index, In-Hospital Complications Risk Stratification Index, overall incidence of

30-day Mortality for each AHRQ-CCS procedure category, overall Incidence of In-hospital Complications for each AHRQ-CCS procedure category, operation hour, day of the week, month of the year, phase of the moon, whether or not the patient resulted in having 30-day mortality, whether or not the patient resulted in having in-hospital complications, and whether or not the patient has the following diseases/disorders: cancer, cardiovascular/cerebrovascular disease, dementia, diabetes, digestive disease, osteoarthritis, psychiatric disorder, pulmonary disease. (some variable definitions provided in Appendix)

Exploratory Data Analysis

Summary Statistics of Baseline Risk Factors for Patients

Predictors	Summary.Statistics
Age(mean/SD)	
Age	57.66 ± 15.04
Gender (count/%)	
Male	14768 (46.15 %)
Female	17230 (53.84 %)
Race (count/%)	
Caucasian	26488 (82.77 %)
African American	3790 (11.84 %)
Other	1243 (3.88 %)
ASA Physical Status (count/%)	
I-II	17261 (53.94 %)
III	13677 (42.74 %)
IV-VI	1055 (3.3 %)
BMI (median/IQR)	
Body Mass Index	28.19 [24.6 , 32.81]
Diseases/Disorders (count/%)	
Cancer	10958 (34.24 %)
Cardiovascular/cerebrovascular disease	16176 (50.55 %)
Dementia	242 (0.76 %)
Diabetes	4166 (13.02 %)
Digestive disease	7037 (21.99 %)
Osteoarthritis	5719 (17.87 %)
Psychiatric disorder	2910 (9.09 %)
Pulmonary disease	3493 (10.92 %)
Indexes (median/IQR)	
Charlson Comorbidity Index	0 [0 , 2]
Risk Stratification Index (30-day mortality)	-0.3 [-1.24 , 0]
Risk Stratification Index (in-hospital complications)	-0.27 [-0.84 , 0]

Summary Statistics of Case Frequencies (Count/%)

Predictors	Summary.Statistics
Hour of Operation	
6:00	562 (1.76 %)
7:00	10631 (33.22 %)
8:00	3807 (11.9 %)
9:00	1664 (5.2 %)
10:00	2501 (7.82 %)
11:00	2855 (8.92 %)
12:00	2763 (8.63 %)
13:00	2623 (8.2 %)
14:00	2063 (6.45 %)
15:00	1267 (3.96 %)
16:00	745 (2.33 %)
17:00	356 (1.11 %)
18:00	163 (0.51 %)
19:00	1 (0 %)
Day of the Week	
Monday	7005 (21.89 %)
Tuesday	7008 (21.9 %)
Wednesday	6266 (19.58 %)
Thursday	5635 (17.61 %)
Friday	6087 (19.02 %)
Month	
January	2670 (8.34 %)
February	2506 (7.83 %)
March	2697 (8.43 %)
April	2698 (8.43 %)
May	2654 (8.29 %)
June	2994 (9.36 %)
July	2325 (7.27 %)
August	3177 (9.93 %)
September	3208 (10.02 %)
October	2689 (8.4 %)
November	2544 (7.95 %)
December	1839 (5.75 %)
Phase of Moon	
New Moon	7708 (24.09 %)
First Quarter	8100 (25.31 %)
Full Moon	8051 (25.16 %)
Last Quarter	8142 (25.44 %)

Methodology

```
model <- glm(mort30 ~ age+hour+dow+month+ moonphase, data = modelData, family = "binomial")

# Display the summary of the model
summary(model)
```

```
##
## Call:
## glm(formula = mort30 ~ age + hour + dow + month + moonphase,
##     family = "binomial", data = modelData)
##
## Coefficients:
##                        Estimate Std. Error z value Pr(>|z|)
## (Intercept)          -10.187427   0.661003 -15.412  < 2e-16 ***
## age                    0.054765   0.006756   8.106 5.21e-16 ***
## hour                   0.129940   0.027345   4.752 2.02e-06 ***
## dowMonday             -0.182428   0.257806  -0.708   0.4792
## dowThursday           -0.183813   0.273734  -0.672   0.5019
## dowTuesday            -0.100698   0.253527  -0.397   0.6912
## dowWednesday          -0.535081   0.284700  -1.879   0.0602 .
## monthAugust           -0.478068   0.442619  -1.080   0.2801
```

```
## monthDecember          -0.664208   0.579286  -1.147   0.2515
## monthFebruary           0.449082   0.379229   1.184   0.2363
## monthJanuary            0.482337   0.371067   1.300   0.1936
## monthJuly               0.110020   0.410410   0.268   0.7886
## monthJune               0.033914   0.395194   0.086   0.9316
## monthMarch              0.003232   0.410111   0.008   0.9937
## monthMay               -0.194284   0.430041  -0.452   0.6514
## monthNovember          -0.812205   0.533872  -1.521   0.1282
## monthOctober           -0.482478   0.458442  -1.052   0.2926
## monthSeptember          0.038993   0.384029   0.102   0.9191
## moonphaseFull Moon      0.200588   0.241455   0.831   0.4061
## moonphaseLast Quarter   0.154164   0.242774   0.635   0.5254
## moonphaseNew Moon       0.022567   0.253383   0.089   0.9290
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 1778.6  on 31998  degrees of freedom
## Residual deviance: 1659.9  on 31978  degrees of freedom
##   (2 observations deleted due to missingness)
## AIC: 1701.9
##
## Number of Fisher Scoring iterations: 9
```

Results

Discussion

Appendix

Extra EDA Visuals

```
## Warning: Removed 2 rows containing non-finite values (`stat_density()`).
```

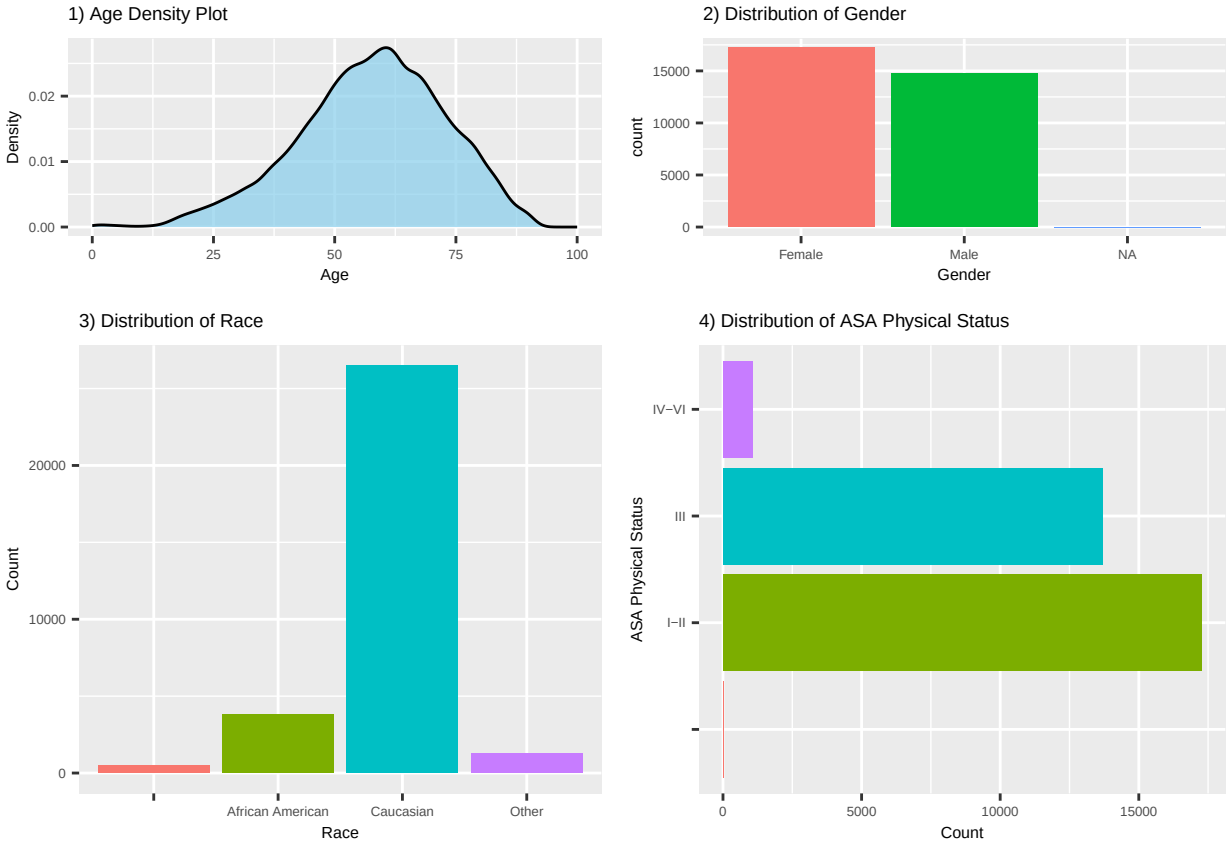


Image 1) Age

Since the distribution of the patients' age is relatively normal and unimodal and not really that skewed to the left the best summary statistic is the mean and the best metric of spread is the standard deviation.

Image 2) Gender

There appears to be a bit more operation cases done on women than men.

Image 3) Race

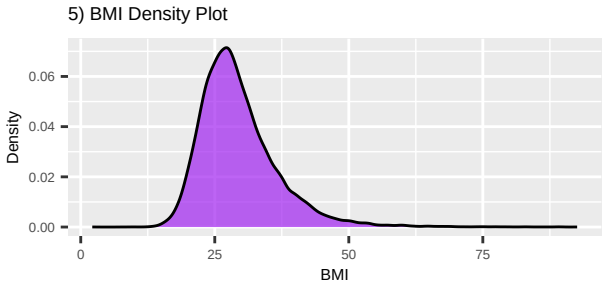
There are multidude more operation cases done on Caucasian patients than any other racial demographics.

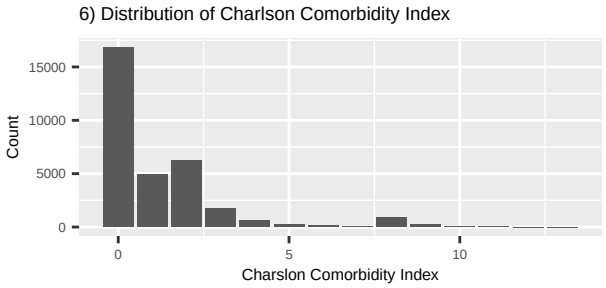
Image 4) ASA Physical Status

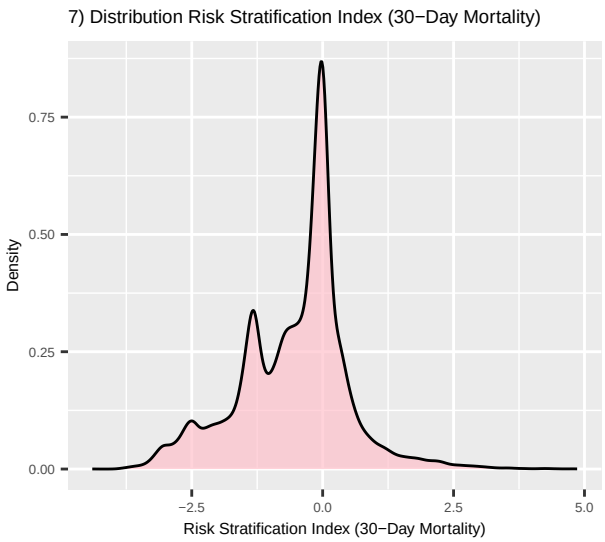
*Note: ASA classification uses a grading system of I (one) through V (five) I identifying a person in good health and V as a person with a severe, life-threatening condition. The sixth (VI) status identifies deceased organ donors.

Most patients of operation cases reside in the I-II ASA status and then the III status comes in a close second. There are not many patients that reside in the IV-VI status.

```
## Warning: Removed 3290 rows containing non-finite values (`stat_density()`).
```







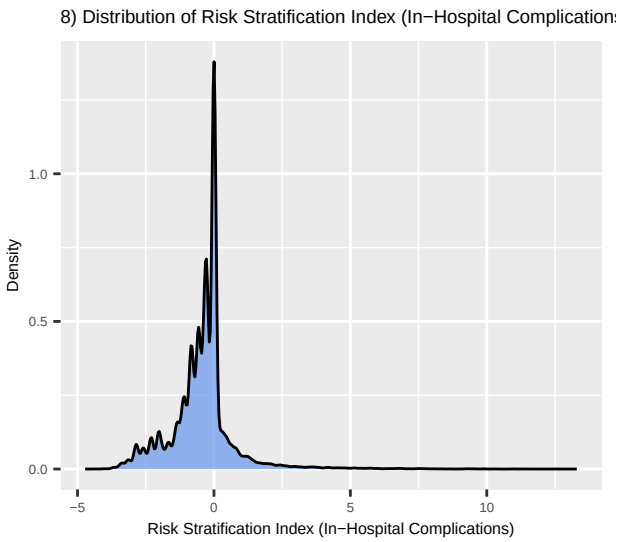


Image 5) BMI

Since the distribution of the patients' BMI is slightly skewed to the right the best summary statistic is the median and the best metric of spread is the IQR.

Image 6) Charlson Comorbidity Index

*Note: The Charlson comorbidity index (CCI) is the most widely used comorbidity index used to determine survival rate (1yr and 10yr) in patient with multiple comorbidities. As the CCI level increases the probability of one year of survival decreases.

Since the distribution of the patients' Charlson Comorbidity Index is skewed to the right the best summary statistic is the median and the best metric of spread is the IQR.

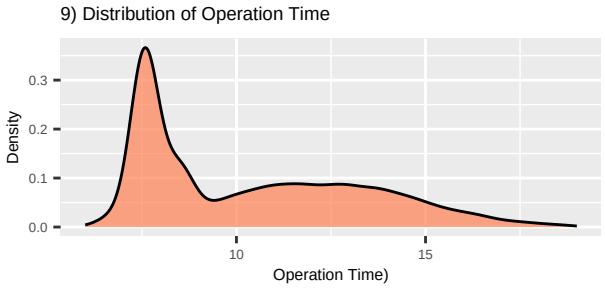
Image 7) Risk Stratification Index (30-Day Mortality)

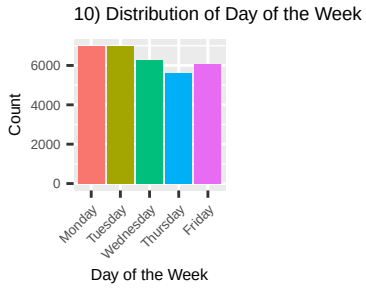
*Note: The Risk Stratification Index (RSI) is an open source, nationally validated, risk stratification methodology that permits outcomes such as duration of hospitalization and mortality to be compared equally across institutions.

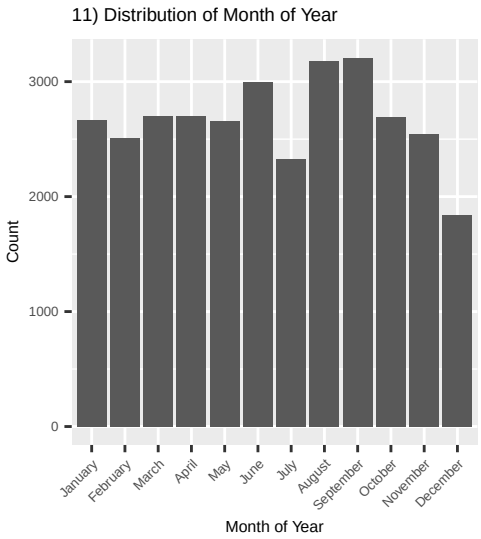
The density chart of the distribution of RSI (30-day mortality) is multimodal and skewed to the left so the median and IQR would be more accurate measures of center and spread.

Image 8) Risk Stratification Index (In-Hospital Complications)

The density chart of the distribution of RSI (in-hospital complications) is multimodal and skewed to the left so the median and IQR would be more accurate measures of center and spread.







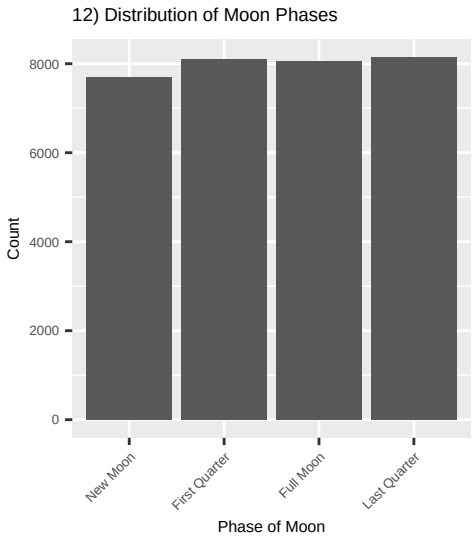


Image 9) Operation Hour

The distribution is bimodal with a huge concentration of operation hours at around 8:00 am and a much smaller concentration at 12:30 pm.

Image 10) Day of the Week

The distribution of the days the of operation cases tend have a higher concentration in the beginning of the week.

Image 11) Month of the Year

The distribution of the months of operation cases show peaks in June and near the end of the summer (August and September).

Image 12) Phase of Moon

The distribution of the moon phases of operation cases show a relatively uniform distribution with the least cases occuring during new moon phases.

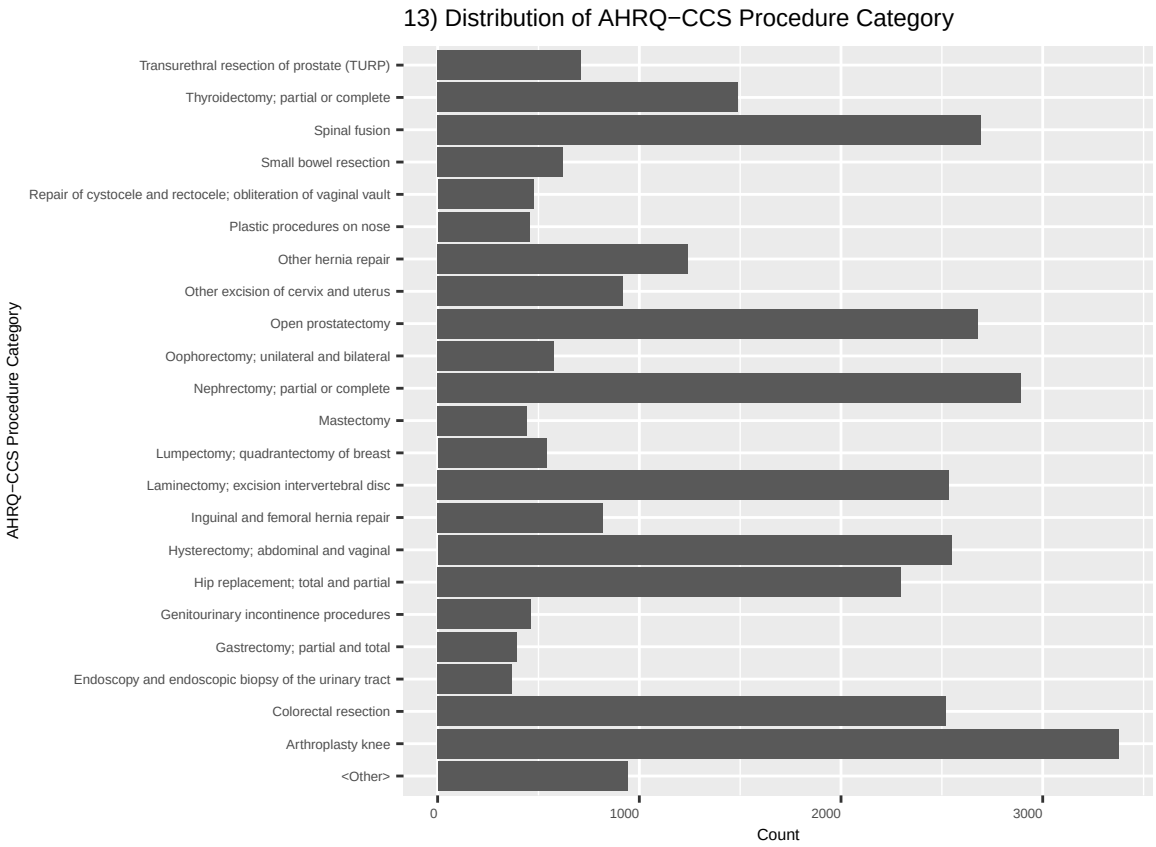
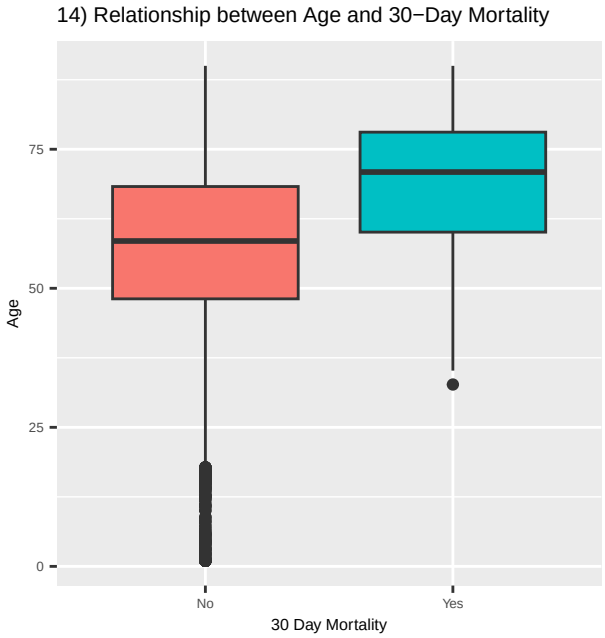


Image 13) AHRQ-CCS Procedure Category

The distribution of procedure type shows there are multiple sporadic procedure types that have very high concentrations of operations and multiple that have low concentrations.

```
## Warning: Removed 2 rows containing non-finite values (`stat_boxplot()`).
```



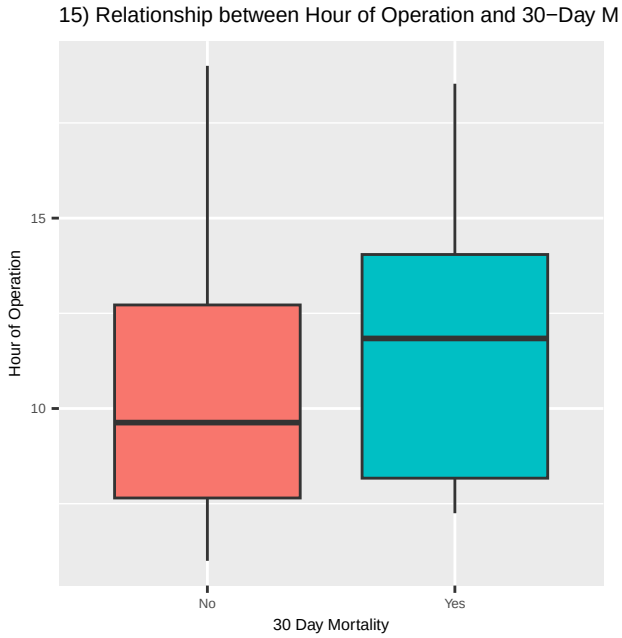


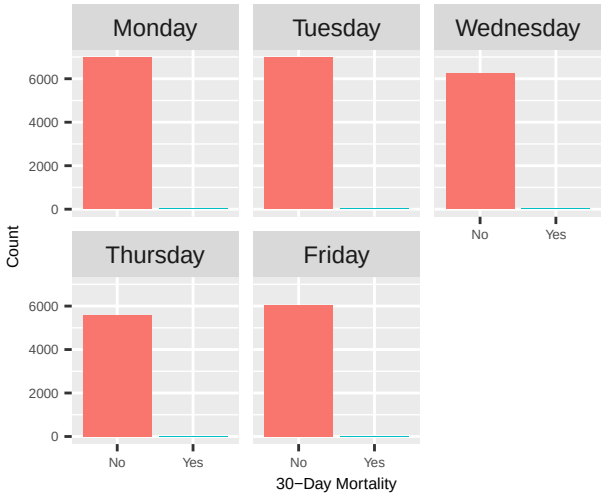
Image 14) Age and 30 Day Morality

The box plots show that operations of patients that have 30-day mortality are more generally of an older age than patients who do not have 30-day mortality.

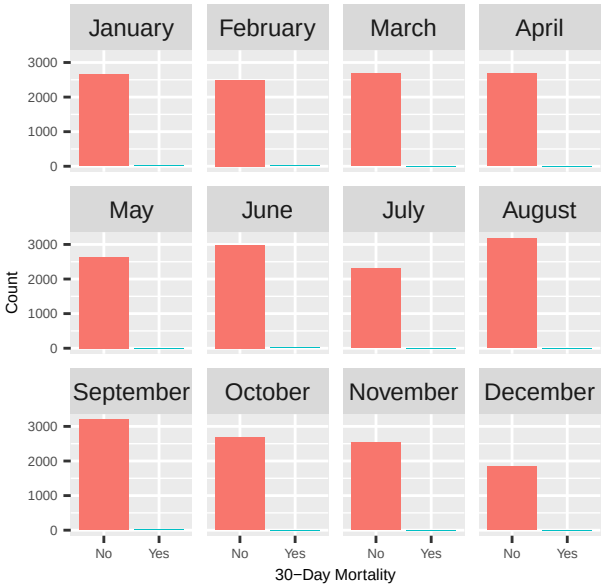
Image 15) Hour and 30 Day Morality

The box plots show that operations of patients that have 30-day mortality tend to happen later in the day than operations of patients that do not have 30-day mortality.

16) Relationship between Day of Operation & 30−Day Mortality



17) Relationship between Month of Operation & 30−Day Mortality




```
## `summarise()` has grouped output by 'dow'. You can override using the `.groups`
## argument.
```

dow	mort30	Count
Monday	No	6975
Monday	Yes	30
Tuesday	No	6976
Tuesday	Yes	32
Wednesday	No	6245
Wednesday	Yes	21
Thursday	No	5611
Thursday	Yes	24
Friday	No	6056
Friday	Yes	31

```
## [1] 0.004282655
```

```
## [1] 0.00456621
```

```
## [1] 0.00335142
```

```
## [1] 0.004259095
```

```
## [1] 0.005092821
```

```
## `summarise()` has grouped output by 'month'. You can override using the
## `.groups` argument.
```

month	mort30	Count
January	No	2651
January	Yes	19
February	No	2489
February	Yes	17
March	No	2685
March	Yes	12
April	No	2686
April	Yes	12
May	No	2644
May	Yes	10
June	No	2980
June	Yes	14
July	No	2313
July	Yes	12
August	No	3168
August	Yes	9
September	No	3192
September	Yes	16
October	No	2681
October	Yes	8
November	No	2539
November	Yes	5
December	No	1835
December	Yes	4

```
## [1] 0.007116105
```

```
## [1] 0.006783719
```

```
## [1] 0.004449388
```

```
## [1] 0.004447739
```

```
## [1] 0.003767898
```

```
## [1] 0.004676019
```

```
## [1] 0.00516129
```

```
## [1] 0.002832861
```

```
## [1] 0.004987531
```

```
## [1] 0.002975084
```

```
## [1] 0.001965409
```

```
## [1] 0.002175095
```

Image 16) Day of Week and 30 Day Mortality

The day with the highest proportion of 30-day mortality cases is Friday, then Tuesday, then Monday, then Thursday, then Wednesday.

Image 17) Month and 30 Day Mortality

The month with the highest proportion of 30-day mortality cases is January, then February, then July.

Work Cited