# **Predictors of Major Complication After Central Cord Syndrome Operation**

**Objective.** The aim of this study is to determine the risk factors that would related to the major complication after central cord syndrome operations.

**Summary of Background Data**. Data were taken from the 2014 HCUP National Inpatient Sample (NIS) database. Risk factors in patient demographics as well as operative features were studied through t-test and chi-square test to determine their association with race and major complications. A step-wise multivariate logistic regression model was used to determine multivariate relationships with major complication.

**Result.** Elder patients discharged to a location that was not home, with a greater length of stay, and greater number of chronic conditions are more likely to have major complication after central cord syndrome operations.

## **Materials and Methods**

Data were collected from 2014 NSQIP database. There are 946 observations and 178 variables in the data set. Ten variables, including sex, age (both continuous and in age ranges), length of stay (LOS), number of chronic conditions (NCHRONIC), Insurance Status (Primarypayer), Urban or Rural Status for patient location (PL\_NCHS), median household income for patient location zip code (ZIPINC\_QRTL), geographic region in the US (HOSP\_DIVISION), Discharge destination (home or not home), and RACE (white and non-white) are of interest to determine if they would be the predictors of the occurrence of major complication. Table1 shows several important variables which are self-created according to other available information in the original data set. Appendix 1 shows relevant CPT code results by race.

As a preliminary study of effect of variable RACE (non-white, white), odds ratios were calculated for operative features and patient characteristics (Table 2). Continuous variables were compared between white and non-white races using two-sample t-tests. There are significant associations between white and non-white race with respect to Sex, AGE (both as continuous and age groups), length of stay (LOS), number of chronic conditions (NCHRONIC), Insurance Status (Primarypayer), Urban or Rural Status for patient location (PL\_NCHS), median household income for patient location zip code (ZIPINC\_QRTL), and geographic region in the US (HOSP\_DIVISION). Take insurance status for example. The odds of non-whites having Medicaid as their primary payer is 2.1921 times the odds of whites. Odds denoted by “1” in Table 2 denote the category used for comparison or the “baseline” group. Continuous variables were compared between those with major complication and those without using a two-sample t-test.

Table 1 Variables recoding notes

| **Variables** | **Notes** |
| --- | --- |
| RACE | coded by collapsing original RACE’s 5 non-white categories to be one |
| Discharge destination | coded by dividing DISPUNIFORM into 2 groups “home” and “not home” |
| primary payer | coded by collapsing Pay1’s “Self-pay” and “No charge” to be “uninsured” |
| complication | coded based on other 30 diagnoses variables describe specific symptom of complication |
| reoperation | coded based on other 30 diagnoses variables describe specific reoperations |
| Major complication | created based on complication, reoperation and DIED |

## **Univariate Analysis**

Table 3 shows the odds ratios of a different risk factors and their 95% confidence intervals.

Take discharge destination as an example. The odds of major complication after cervical fusion operations is 3.1148 times greater for those patients discharged to somewhere other than home compared to those discharged home. Odds denoted by “1” in Table 3 denote the category used for comparison or the “baseline” group. Continuous variables were compared between those with major complication and those without using a two-sample t-test. Appendix 2 shows relevant diagnostic codes by major complication.

## **Multivariate Analysis**

A stepwise multivariate logistic regression was conducted on the data set with 945 non-missing observations and Table 4 shows the model results. A final model was chosen based on AIC value. Based on 0.05 significance level, AGE (continuous), length of stay (LOS), number of chronic conditions (NCHRONIC), and Discharge destination (home, not home) are significant predictors of major complications. Figure 1 shows the ROC of the final model and the area under the curve (AUC) is 0.7968 with a 95% confidence interval [0.7674, 0.8263].

The selection of cut-offs does not influence the modeling procedure (coefficients estimations, odds ratios and other statistics, Table 4) and resulting predicted probabilities. However, the misclassification rate and the power of the prediction are highly related to the cut-off setting used since these are used to predict an observation to be "1" or "0" (using the predicted probability). According to confusion table (Table 5), if the commonly used 0.5 is used as the prediction cut-off, the type I error will be extremely small but the power is small as well. But if the Youden’s Index value is used as the cut-off, this maximizes the sum of sensitivity and specificity, the power increases to 0.7027 while the type I error also increases dramatically. There is always a tradeoff between sensitivity and specificity. Youden’s index is recommended here since it’s a cut-off which equally weights sensitivity and specificity.

Figure 1 ROC curve of the final model

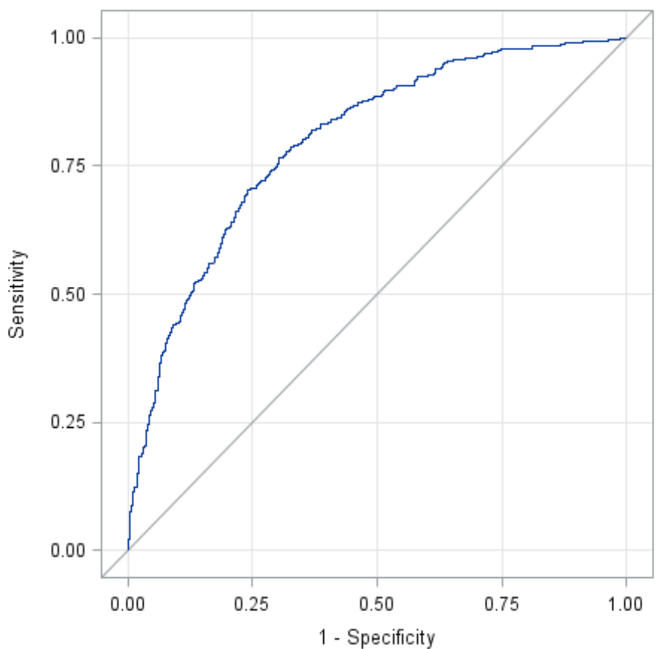


Table 5 Confusion matrix at different cutoffs of regular logistic regression

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| cutoff=0.5 (commen used) | **predict** | **response** | | **Sensitivity** | **Specificity** | **Type I error** | **Type II error** |
| **1** | **0** |
| 1 | 163 | 75 | 0.489 | 0.877 | 0.123 | 0.511 |
| 0 | 170 | 537 |
| cutoff= 0.382 (Youden's Index) | **predict** | **response** | | **Sensitivity** | **Specificity** | **Type I error** | **Type II error** |
| **1** | **0** |
| 1 | 234 | 147 | 0.7027 | 0.7598 | 0.2402 | 0.2973 |
| 0 | 99 | 465 |
| cutoff=0.031 (maxmize detection of majorcomplication) | **predict** | **response** | | **Sensitivity** | **Specificity** | **Type I error** | **Type II error** |
| **1** | **0** |
| 1 | 333 | 604 | 1 | 0.0131 | 0.9869 | 0 |
| 0 | 0 | 8 |
| cutoff=0.999 (minimize type I error) | **predict** | **response** | | **Sensitivity** | **Specificity** | **Type I error** | **Type II error** |
| **1** | **0** |
| 1 | 1 | 0 | 0.0030 | 1 | 0 | 0.9970 |
| 0 | 332 | 612 |

## **Results and Discussion**

Table 6 shows the comparison between univariate analysis and multivariate analysis for major complication. It seems that the univariate results identified more variables as risk factors for major complication than with multivariate relationships through the stepwise logistic regression. But they give consistent overall conclusions, [i.e., elder patients, discharged to a place other than home, with greater length of stay, and more chronic conditions, are more likely to have major complications after central cord syndrome operations.]

Table 6 Comparison between univariate analysis and multivariate analysis

| **Variable** | **Risk factor** | **significance** | |
| --- | --- | --- | --- |
| **Univariate** | **Multivariate** |
| SEX | male | non-significant | non-significant |
| AGE |  | significant | significant |
| Length of stay (LOS) |  | significant | significant |
| # of chronic conditions (NCHRONIC) |  | significant | significant |
| Primary Payer | medicaid | significant | non-significant |
| medicare | significant | non-significant |
| uninsured | non-significant | non-significant |
| Rural vs Urban  (PL\_NCHS) | Fringe | non-significant | non-significant |
| >250,000 POP | non-significant | non-significant |
| <250,000 POP | non-significant | non-significant |
| Micropolitan | non-significant | non-significant |
| Not metropolitan | significant | non-significant |
| Median Household income  (ZIPINC\_QRTL) | $39,000 - $47,999 | non-significant | non-significant |
| $48,000 - 62,999 | non-significant | non-significant |
| $63,000 or more | non-significant | non-significant |
| Region  (HOSP\_DIVISION) | MA | non-significant | non-significant |
| ENC | non-significant | non-significant |
| WNC | non-significant | non-significant |
| SA | non-significant | non-significant |
| ESC | non-significant | non-significant |
| WSC | non-significant | non-significant |
| Mountain | non-significant | non-significant |
| Pacific | non-significant | non-significant |
| Discharge Destination | not home | significant | significant |
| race | Non-White | non-significant | non-significant |

Table 2 Summary of Patients and Operative features by different race group

| **Variable** | **Category** | **All patients**  **N %** | | **White (N=593)**  **N %** | | **Non-white (N=292)**  **N %** | | **OR** | **95% CI** | **P-value** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SEX | female | 251 | 28.36% | 181 | 30.52% | 70 | 23.97% | 1 |  |  |
| male | 634 | 71.64% | 412 | 69.48% | 222 | 76.03% | 1.3933 | [1.0112,1.9197] | 0.0473 |
| Age group | 18-30 | 24 | 2.72% | 13 | 2.20% | 11 | 3.77% | 1 |  |  |
| 31-40 | 51 | 5.78% | 32 | 5.42% | 19 | 6.51% | 0.7017 | [0.2625,1.8759] | 0.6141 |
| 41-50 | 101 | 11.45% | 52 | 8.81% | 49 | 16.78% | 1.1136 | [0.4561,2.7193] | 0.8249 |
| 51-60 | 231 | 26.19% | 139 | 23.56% | 92 | 31.51% | 0.7822 | [0.336,1.8211] | 0.6632 |
| 61-70 | 212 | 24.04% | 147 | 24.92% | 65 | 22.26% | 0.5226 | [0.2224,1.228] | 0.1662 |
| 70+ | 263 | 29.82% | 207 | 35.08% | 56 | 19.18% | 0.3197 | [0.1359,0.7522] | 0.0108 |
| Primary Payer | private | 263 | 32.19% | 184 | 32.74% | 79 | 30.98% | 1 |  |  |
| medicaid | 99 | 12.12% | 51 | 9.07% | 48 | 18.82% | 2.1921 | [1.3643,3.5221] | 0.0013 |
| medicare | 398 | 48.71% | 298 | 53.02% | 100 | 39.22% | 0.7816 | [0.5521,1.1064] | 0.18 |
| uninsured | 57 | 6.98% | 29 | 5.16% | 28 | 10.98% | 2.2488 | [1.2561,4.026] | 0.0081 |
| Rural vs Urban  (PL\_NCHS) | Central | 244 | 27.85% | 122 | 20.71% | 122 | 42.51% | 1 |  |  |
| Fringe | 202 | 23.06% | 146 | 24.79% | 56 | 19.51% | 0.3836 | [0.2578,0.5707] | <0.0001 |
| >250,000 POP | 215 | 24.54% | 151 | 25.64% | 64 | 22.30% | 0.4238 | [0.2883,0.6231] | <0.0001 |
| <250,000 POP | 68 | 7.76% | 52 | 8.83% | 16 | 5.57% | 0.3077 | [0.1665,0.5685] | 0.0001 |
| Micropolitan | 79 | 9.02% | 62 | 10.53% | 17 | 5.92% | 0.2742 | [0.1516,0.4958] | <0.0001 |
| Not metropolitan | 68 | 7.76% | 56 | 9.51% | 12 | 4.18% | 0.2143 | [0.1094,0.4196] | <0.0001 |
| Median Household income  (ZIPINC\_QRTL) | $1 - $38,999 | 263 | 30.58% | 140 | 24.14% | 123 | 43.93% | 1 |  |  |
| $39,000 - $47,999 | 228 | 26.51% | 166 | 28.62% | 62 | 22.14% | 0.4251 | [0.291,0.6211] | <0.0001 |
| $48,000 - 62,999 | 203 | 23.60% | 155 | 26.72% | 48 | 17.14% | 0.3525 | [0.2353,0.5281] | <0.0001 |
| $63,000 or more | 166 | 19.30% | 119 | 20.52% | 47 | 16.79% | 0.4495 | [0.2967,0.6812] | 0.0002 |
| Region  (HOSP\_DIVISION) | NE | 47 | 5.31% | 44 | 7.42% | 3 | 1.03% | 1 |  |  |
| MA | 98 | 11.07% | 60 | 10.12% | 38 | 13.01% | 9.2889 | [2.6931,32.0388] | <0.0001 |
| ENC | 134 | 15.14% | 95 | 16.02% | 39 | 13.36% | 6.0211 | [1.7643,20.5482] | 0.0011 |
| WNC | 50 | 5.65% | 41 | 6.91% | 9 | 3.08% | 3.2195 | [0.8147,12.723] | 0.1229 |
| SA | 190 | 21.47% | 111 | 18.72% | 79 | 27.05% | 10.4384 | [3.1295,34.8169] | <0.0001 |
| ESC | 69 | 7.80% | 57 | 9.61% | 12 | 4.11% | 3.0877 | [0.8208,11.6155] | 0.0977 |
| WSC | 94 | 10.62% | 54 | 9.11% | 40 | 13.70% | 10.8642 | [3.1472,37.5035] | <0.0001 |
| Mountain | 62 | 7.01% | 40 | 6.75% | 22 | 7.53% | 8.0667 | [2.2427,29.014] | 0.0004 |
| Pacific | 141 | 15.93% | 91 | 15.35% | 50 | 17.12% | 8.0586 | [2.3806,27.2791] | 0.0001 |
| Discharge Destination | home | 377 | 42.65% | 250 | 42.16% | 127 | 43.64% | 1 |  |  |
| not home | 507 | 57.35% | 343 | 57.84% | 164 | 56.36% | 0.9412 | [0.709,1.2494] | 0.7176 |
| complication | No | 575 | 64.97% | 377 | 63.58% | 198 | 67.81% | 1 |  |  |
| Yes | 310 | 35.03% | 216 | 36.42% | 94 | 32.19% | 0.8286 | [0.6157,1.1152] | 0.2308 |
| reoperation | No | 876 | 98.98% | 586 | 98.82% | 290 | 99.32% | 1 |  |  |
| Yes | 9 | 1.02% | 7 | 1.18% | 2 | 0.68% | 0.5773 | [0.1192,2.7968] | 0.7255 |
| **Variable** |  | **All patients**  **Mean Std Dev** | | **White (N=593)**  **Mean Std Dev** | | **Non-white (N=292)**  **Mean Std Dev** | |  |  | **P-value**  **t-test** |
| AGE\* |  | 61.57 | 14.88 | 63.35 | 14.8 | 58.32 | 14.34 |  |  | <0.0001 |
| Length of stay (LOS)\* |  | 9.83 | 11.21 | 9.31 | 10.99 | 11.18 | 11.89 |  |  | 0.0208 |
| # of chronic conditions\*  (NCHRONIC) |  | 6.39 | 3.32 | 6.54 | 3.35 | 6.07 | 3.22 |  |  | 0.0472 |

\* for numerical variables like AGE the means and the standard deviations are given for different race groups, and the p-values are based on two sample t-tests.

Table 3 Univariate Analysis of risk factors for Major Complication

| **Variable** | **Risk Factor** | **No Major Complications**  **(N=612)**  **N %** | | **Major Complications**  **(N=334)**  **N %** | | **OR** | **95% CI of OR** | **P-value** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SEX | female | 161 | 26.31% | 104 | 31.14% | 1 |  |  |
| male | 451 | 73.69% | 230 | 68.86% | 0.7895 | [0.5888,1.0586] | 0.1297 |
| Age group | 18-30 | 22 | 3.61% | 4 | 1.20% | 1 |  |  |
| 31-40 | 50 | 8.21% | 4 | 1.20% | 0.44 | [0.1008,1.9211] | 0.4268 |
| 41-50 | 88 | 14.45% | 20 | 6.01% | 1.25 | [0.3877,4.0307] | 1 |
| 51-60 | 179 | 29.39% | 71 | 21.32% | 2.1816 | [0.726,6.5555] | 0.2451 |
| 61-70 | 143 | 23.48% | 81 | 24.32% | 3.1154 | [1.0373,9.3562] | 0.0472 |
| 70+ | 127 | 20.85% | 153 | 45.95% | 6.626 | [2.2254,19.7281] | 0.0001 |
| Primary Payer | private | 219 | 39.46% | 71 | 22.33% | 1 |  |  |
| medicaid | 66 | 11.89% | 37 | 11.64% | 1.7292 | [1.0664,2.804] | 0.0292 |
| medicare | 222 | 40% | 199 | 62.58% | 2.7649 | [1.9897,3.8422] | <0.0001 |
| uninsured | 48 | 8.65% | 11 | 3.46% | 0.7069 | [0.3483,1.4345] | 0.4013 |
| Rural vs Urban  (PL\_NCHS) | Central | 173 | 28.55% | 85 | 25.68% | 1 |  |  |
| Fringe | 134 | 22.11% | 78 | 23.56% | 1.1847 | [0.8092,1.7345] | 0.436 |
| >250,000 POP | 145 | 23.93% | 76 | 22.96% | 1.0668 | [0.7295,1.56] | 0.7714 |
| <250,000 POP | 52 | 8.58% | 29 | 8.76% | 1.1351 | [0.6727,1.9154] | 0.6863 |
| Micropolitan | 60 | 9.90% | 25 | 7.55% | 0.848 | [0.4972,1.4464] | 0.5935 |
| Not metropolitan | 42 | 6.93% | 38 | 11.48% | 1.8415 | [1.1059,3.0661] | 0.0235 |
| Median Household income  (ZIPINC\_QRTL) | $1 - $38,999 | 173 | 28.93% | 99 | 30.65% | 1 |  |  |
| $39,000 - $47,999 | 155 | 25.92% | 96 | 29.72% | 1.0823 | [0.7591,1.5431] | 0.7174 |
| $48,000 - 62,999 | 145 | 24.25% | 74 | 22.91% | 0.8918 | [0.6139,1.2955] | 0.5695 |
| $63,000 or more | 125 | 20.90% | 54 | 16.72% | 0.7549 | [0.5042,1.1302] | 0.187 |
| Region  (HOSP\_DIVISION) | NE | 33 | 5.39% | 14 | 4.19% | 1 |  |  |
| MA | 68 | 11.11% | 33 | 9.88% | 1.1439 | [0.5399,2.4236] | 0.85 |
| ENC | 91 | 14.87% | 50 | 14.97% | 1.2951 | [0.6342,2.645] | 0.5943 |
| WNC | 51 | 8.33% | 25 | 7.49% | 1.1555 | [0.5258,2.539] | 0.8424 |
| SA | 122 | 19.93% | 77 | 23.05% | 1.4877 | [0.7483,2.9577] | 0.3142 |
| ESC | 43 | 7.03% | 26 | 7.78% | 1.4252 | [0.6453,3.148] | 0.43 |
| WSC | 62 | 10.13% | 32 | 9.58% | 1.2166 | [0.5708,2.5932] | 0.7044 |
| Mountain | 48 | 7.84% | 28 | 8.38% | 1.375 | [0.6305,2.9988] | 0.4421 |
| Pacific | 94 | 15.36% | 49 | 14.67% | 1.2287 | [0.6016,2.5097] | 0.5981 |
| Discharge Destination | home | 316 | 51.63% | 85 | 25.53% | 1 |  |  |
| not home | 296 | 48.37% | 248 | 74.47% | 3.1148 | [2.3238,4.175] | <0.0001 |
| race | White | 373 | 65.32% | 220 | 70.06% | 1 |  |  |
| Non-White | 198 | 34.68% | 94 | 29.94% | 0.8049 | [0.5983,1.0829] | 0.1565 |
| **Variable** | **Risk Factor** | **No Major (N=612)**  **Mean Std Dev** | | **Major (N=334)**  **Mean Std Dev** | |  |  | **P-value**  **t-test** |
| AGE |  | 58.38 | 14.73 | 67.43 | 13.29 |  |  | <0.0001 |
| LOS |  | 7.17 | 7.64 | 14.69 | 14.59 |  |  | <0.0001 |
| # of chronic (NCHRONIC) |  | 5.51 | 2.89 | 7.99 | 3.45 |  |  | <0.0001 |

\* for numerical variables like AGE the means and the standard deviations are given for different major complication groups, and the p-values are based on two sample t-tests.

Table 4 Coefficients of Logistic Regression

| **Variable** | **Risk Factor** | **Odds** | **Estimate** | **Std.Error** | **z value** | **p-value** | **Association type** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept |  |  | -4.4815 | 0.4226 | 112.436 | <.0001 |  |
| Age (cont.) |  | 1.034 | 0.0332 | 0.0062 | 28.7323 | <.0001 | positive |
| Length of stay (cont.) |  | 1.07 | 0.0673 | 0.00972 | 47.8714 | <.0001 | positive |
| # chronic conditions NCHRONIC(cont.) |  | 1.161 | 0.1497 | 0.0259 | 33.4827 | <.0001 | positive |
| Discharge destination | not home | 2.026 | 0.353 | 0.0853 | 17.1346 | <.0001 | positive |

## NHIS

*Background on Data[[1]](#footnote-1)*

The National Health Interview Survey (NHIS) has monitored the health of the nation since 1957. NHIS data on a broad range of health topics are collected through personal household interviews. For over 50 years, the U.S. Census Bureau has been the data collection agent for the National Health Interview Survey. Survey results have been instrumental in providing data to track health status, health care access, and progress toward achieving national health objectives. Some more information can be found [here](https://www.cdc.gov/nchs/nhis/index.htm).

*Typical Analyses Run*

Analysis of NHIS data are similar with NIS data. The example report shown on the following section indicates the analyzing process. The purpose is to determine the risk factors that would related to operative features (e.g., readmission) after some specific operations (e.g., cervical spine fusion surgery). Two sample t-test and chi-square test were used to analysis continuous and discrete variables to determine their association with operative features of interest. Then a step-wise multivariate logistic regression model was used to determine multivariate relationship with operative features of interest. As same with NIS data analysis, ROC curve and confusion matrix were used to decide the cut-off points. Consequently, the risk factors were determined by comparing result of univariate and multivariate analysis.

*Example Report*

The example report reveals the risk factors of readmission after taking cervical spine fusion surgery.

# **Retrospective MU Cervical Spine Fusion Study**

**Objective.** The aim of this study is to determine the risk factors that would be related to different outcomes after cervical spine fusion surgery.

**Summary of Background Data**. Risk factors in patient demographics as well as operative features are studied through chi-square tests, t-tests, and multivariate logistic regression to determine their association with outcomes of interest.

**Result.** The risk factors for readmission that both univariate analyses and multivariate analyses identified is variables implant loosing, pseduoarthrosis, and adjacent segment disease.

## **Materials and Methods**

Data were retrospectively collected from EMRs. There are 256 observations.

As a preliminary study of effect of variable RACE, a summary of all demographic, socioeconomic, and clinical variables were compared using chi-square tests for association and the associated odds ratios were calculated, as Table 1 shows. There are significant associations between white and non-white race with respect to wound complication - infection. Take it for example, the odds ratio of “Non-white” to “White” is 13.1111, and the p-value is less than 0.05, which means the non-white patients have higher odds of Wound complication - infection compared to white patients.

Table 1. Demographic information for patients by different race group

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Category | All patients  （N=256） | | White (N=237) | | Non-white (N=19) | | OR | 95% CI | Pvalue |
| SEX | male | 99 | 38.67% | 95 | 40.08% | 4 | 21.05% | 1 |  |  |
| female | 157 | 61.33% | 142 | 59.92% | 15 | 78.95% | 2.5088 | [0.8079, 7.7906] | 0.1019 |
| Insurance | private | 151 | 58.98% | 141 | 59.49% | 10 | 52.63% | 1 |  |  |
|  | Medicare/Medicare & Medicaid | 23 | 8.98% | 20 | 8.44% | 3 | 15.79% | 2.115 | [0.5361, 8.3447] | 0.2766 |
|  | Medicaid | 78 | 30.47% | 72 | 30.38% | 6 | 31.58% | 1.175 | [0.4107, 3.3617] | 0.7639 |
|  | Self-Pay | 4 | 1.56% | 4 | 1.69% | 0 | 0.00% | 0 |  |  |
| Diabetes | No | 214 | 83.59% | 200 | 84.39% | 14 | 73.68% | 1 |  |  |
| Yes | 42 | 16.41% | 37 | 15.61% | 5 | 26.32% | 1.9305 | [0.6558, 5.6829] | 0.2263 |
| Smoking | No | 178 | 69.53% | 167 | 70.46% | 11 | 57.89% | 1 |  |  |
| Yes | 78 | 30.47% | 70 | 29.54% | 8 | 42.11% | 1.7351 | [0.6693, 4.4977] | 0.253 |
| ASACLAS | 1-2 | 138 | 53.91% | 128 | 54% | 10 | 52.63% | 1 |  |  |
| 3-5 | 116 | 45.31% | 107 | 45.15% | 9 | 47.37% | 1.0766 | [0.4221, 2.7463] | 0.8774 |
| Age group | 18-30 | 2 | 0.78% | 2 | 0.84% | 0 | 0% | 0 |  |  |
| 31-40 | 35 | 13.67% | 33 | 13.92% | 2 | 10.53% | 1 |  |  |
| 41-50 | 105 | 41.01% | 98 | 41.35% | 7 | 36.84% | 1.1786 | [0.2332, 5.9567] | 0.8429 |
| 51-60 | 74 | 28.91% | 67 | 28.27% | 7 | 36.84% | 1.7239 | [0.3392, 8.7617] | 0.5091 |
| 61-70 | 30 | 11.72% | 28 | 11.81% | 2 | 10.53% | 1.1786 | [0.1558, 8.9167] | 0.8744 |
| 70+ | 10 | 4.10% | 9 | 3.80% | 1 | 5.26% | 1.8333 | [0.1488, 22.5830] | 0.6356 |
| Hypertension | No | 141 | 55.08% | 134 | 56.54% | 7 | 36.84% | 1.0000 |  |  |
| Yes | 115 | 44.92% | 103 | 43.46% | 12 | 63.16% | 2.2302 | [0.8481, 5.8649] | 0.0974 |
| DIALYSIS | No | 256 | 100% | 237 | 100% | 19 | 100% | 1 |  |  |
| Yes | 0 | 0% | 0 | 0% | 0 | 0% | 0 |  |  |
| Active Cancer | No | 249 | 97.27% | 230 | 97.05% | 19 | 100% | 1 |  |  |
| Yes | 7 | 2.73% | 7 | 2.95% | 0 | 0% | 0 |  |  |
| wound complication – hematoma or seroma | No | 255 | 99.61% | 236 | 99.58% | 19 | 100% | 1 |  |  |
| Yes | 1 | 0.39% | 1 | 0.42% | 0 | 0% | 0 |  |  |
| Wound complication - infection | No | 254 | 99.22% | 236 | 99.58% | 18 | 94.74% | 1 |  |  |
| Yes | 2 | 0.78% | 1 | 0.42% | 1 | 5.26% | 13.1111 | [0.7870, 218.415] | 0.02135 |
| Implant loosening | No | 227 | 88.67% | 211 | 89.03% | 16 | 84.21% | 1 |  |  |
| Yes | 29 | 11.33% | 26 | 10.97% | 3 | 15.79% | 1.5216 | [0.4152, 5.5759] | 0.5245 |
| Implant breakage | No | 251 | 98.05% | 232 | 97.89% | 19 | 100% | 1 |  |  |
| Yes | 5 | 1.95% | 5 | 2.11% | 0 | % | 0 |  |  |
| any complication (wound, surgical, infection) | No | 173 | 67.58% | 162 | 68.35% | 11 | 57.89% | 1 |  |  |
| Yes | 83 | 32.42% | 75 | 31.65% | 8 | 42.11% | 2.3582 | [0.8803, 6.3167] | 0.0809 |
| Destination post-op | home | 247 | 96.48% | 228 | 96.20% | 19 | 100% | 1 |  |  |
|  | Not home | 9 | 3.52% | 9 | 3.80% | 0 | 0% | 0 |  |  |
| comorbidities | no | 84 | 32.81% | 81 | 34.18% | 3 | 15.79% | 1 |  |  |
|  | yes | 172 | 67.19% | 156 | 65.82% | 16 | 84.21% | 2.7692 | [0.7839, 9.7822] | 0.1012 |
| pseudoarthrosis | no | 230 | 89.84% | 213 | 89.87% | 17 | 89.47% | 1 |  |  |
|  | yes | 26 | 10.16% | 24 | 10.13% | 2 | 10.53% | 1.0441 | [0.2273, 4.7966] | 0.9558 |
| Adjacent segment disease | no | 234 | 91.41% | 217 | 91.56% | 17 | 89.47% | 1 |  |  |
|  | yes | 22 | 8.59% | 20 | 8.44% | 2 | 10.53% | 1.2765 | [0.2750, 5.9250] | 0.7552 |
| Proximal junctional fracture | no | 251 | 98.05% | 233 | 98.31% | 18 | 94.74% | 1 |  |  |
|  | yes | 5 | 1.95% | 4 | 1.69% | 1 | 5.26% | 3.2361 | [0.3434, 30.4938] | 0.2795 |
| readmission | No | 193 | 75.39% | 181 | 76.37% | 12 | 63.16% | 1 |  |  |
| Yes | 63 | 24.61% | 56 | 23.63% | 7 | 36.84% | 1.8854 | [0.7082, 1.8854] | 0.1991 |
| Revision surgeries | No | 203 | 79.30% | 191 | 80.59% | 12 | 63.16% | 1 |  |  |
| Yes | 53 | 20.70% | 46 | 19.41% | 7 | 36.84% | 2.4221 | [0.9035, 6.4935] | 0.0717 |
| BMIgroup | <=35 | 202 | 78.91% | 188 | 79.32% | 14 | 73.68% |  |  |  |
| 35+ | 54 | 21.09% | 49 | 20.68% | 5 | 26.32% | 1.3703 | [0.4708, 3.9885] | 0.5628 |
| COPD | No | 229 | 89.45% | 213 | 89.87% | 16 | 84.21% | 1 |  |  |
| Yes | 27 | 10.55% | 24 | 10.13% | 3 | 15.79% | 1.6641 | [0.4520,6.1263] | 0.4403 |
| BMI |  | 30.65 | 6.77 | 30.54 | 6.76 | 32.05 | 6.69 |  |  | 0.3474 |
| AGE |  | 50.45 | 9.98 | 50.44 | 10.09 | 50.63 | 9 |  |  | 0.9357 |
| Delta VAS |  | 1.62 | 3.00 | 1.74 | 2.97 | 0.21 | 2.99 |  |  | 0.0323 |
| Pre-op VAS |  | 6.15 | 2.60 | 6.14 | 2.53 | 6.32 | 3.54 |  |  | 0.8342 |
| Post-op VAS |  | 4.46 | 3.13 | 4.34 | 3.09 | 6 | 3.32 |  |  | 0.0258 |
| Median Income |  | 45787.54 | 10458.01 | 45884.04 | 10505.58 | 44474.12 | 10364.01 |  |  | 0.5933 |

## **Univariate Analysis**

Univariate analyses of readmission risk factors were performed through chi-square tests and the associated odds ratio was reported. The readmission variable has two measurements, “Yes” and “No”. In addition, a stepwise multivariate logistic regression was performed to determine significant predictors.

Table 2 shows the odds ratios of a series potential risk factors and their 95% confidence intervals and p-values of the odds ratio tests. Take implant loosening for instance, the odds ratio of “Yes” to “No” is 11.5625, and the p-value is less than 0.05, which means the patients who have implant loosening will have higher odds of a readmission after cervical operations. And it is similar to the factors, complication, pseduoarthrosis, adjacent segment disease, and revision surgeries, which are other risk factors would result in readmission.

Table 2 Univariate Analysis of risk factors for any readmission

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Category | Any readmission  (N=63) | | No readmission  (N=193) | | OR | 95% CI | Pvalue |
| SEX | male | 30 | 47.62% | 69 | 35.75% | 1 |  |  |
| female | 33 | 52.38% | 124 | 64.25% | 0.6121 | [0.3443,1.0882] | 0.10267 |
| Insurance | private | 39 | 61.90% | 112 | 58.03% | 1 |  |  |
| Medicare/Medicare & Medicaid | 3 | 4.76% | 20 | 10.36% | 0.4308 | [0.1213,1.5294] | 0.2940 |
| Medicaid | 20 | 31.75% | 58 | 30.05% | 0.9903 | [0.5298,1.8508] | 1 |
| Self-Pay | 1 | 1.59% | 3 | 1.55% | 0.9573 | [0.0967,9.4749] | 1 |
| Diabetes | No | 53 | 84.13% | 161 | 83.42% | 1 |  |  |
| Yes | 10 | 15.87% | 32 | 16.58% | 0.9493 | [0.4374,2.0604] | 1 |
| Smoking | No | 41 | 65.08% | 137 | 70.98% | 1 |  |  |
| Yes | 22 | 34.92% | 56 | 29.02% | 1.3127 | [0.7175,2.4018] | 0.4310 |
| ASACLAS | 1-2 | 30 | 47.62% | 108 | 55.96% | 1 |  |  |
| 3-5 | 33 | 52.38% | 83 | 43.01% | 1.4313 | [0.8085,205341] | 0.2446 |
| Age group | 18-30 | 0 | 0% | 2 | 1.04% | 0 |  |  |
| 31-40 | 8 | 12.70% | 27 | 13.99% | 1 | [0.4021,2.4868] | 1 |
| 41-50 | 24 | 38.10% | 81 | 41.97% | 1 |  |  |
| 51-60 | 18 | 28.57% | 56 | 29.02% | 1.0848 | [0.5389,2.1838] | 0.8589 |
| 61-70 | 9 | 14.29% | 21 | 10.88% | 1.4464 | [0.5857,3.5719] | 0.4722 |
| 70+ | 4 | 6.35% | 6 | 3.11% | 2.25 | [0.5864,8.6329] | 0.2542 |
| Hypertension | No | 31 | 49.21% | 110 | 56.99% | 1 |  |  |
| Yes | 32 | 50.79% | 83 | 43.01% | 1.3681 | [0.7735,2.4197] | 0.3089 |
| DIALYSIS | No | 63 | 100% | 193 | 100% | 1 |  |  |
| Yes | 0 | 0% | 0 | 0% | 0 |  |  |
| Active Cancer | No | 63 | 100% | 186 | 96.37% | 1 |  |  |
| Yes | 0 | 0% | 7 | 3.63% | 0 |  |  |
| wound complication – hemoatoma or seroma | No | 63 | 100% | 192 | 99.48% | 1 |  |  |
| Yes | 0 | 0% | 1 | 0.52% | 0 |  |  |
| Wound complication - infection | No | 61 | 96.83% | 193 | 100% | 1 |  |  |
| Yes | 2 | 3.17% | 0 | 0% | 0 |  |  |
| Implant loosening | No | 42 | 66.67% | 185 | 95.85% | 1 |  |  |
| Yes | 21 | 33.33% | 8 | 4.15% | 11.5625 | [4.7934,27.8909] | 8.248e-9 |
| Implant breakage | No | 60 | 95.24% | 191 | 98.96% | 1 |  |  |
| Yes | 3 | 4.76% | 2 | 1.04% | 4.775 | [0.7795,29.2520] | 0.0974 |
| comorbidities | no | 17 | 26.98% | 67 | 34.72% | 1 |  |  |
| yes | 46 | 73.02% | 126 | 65.28% | 1.4388 | [0.7661,2.7024] | 0.2826 |
| pseduoarthrosis | no | 44 | 69.84% | 186 | 96.37% | 1 |  |  |
| yes | 19 | 30.16% | 7 | 3.63% | 11.4740 | [4.5417,28.9875] | 4.3138e-8 |
| Adjacent segment disease | no | 48 | 76.19% | 186 | 96.37% | 1 |  |  |
| yes | 15 | 23.81% | 7 | 3.63% | 8.3036 | [3.2062,21.5052] | 7.222e-6 |
| Proximal junctional fracture | no | 61 | 96.83% | 190 | 98.44% | 1 |  |  |
| yes | 2 | 3.17% | 3 | 1.55% | 2.0765 | [0.3390,12.7175] | 0.5993 |
| Revision surgeries | No | 12 | 19.05% | 191 | 98.96% | 1 |  |  |
| Yes | 51 | 80.95% | 2 | 1.04% | 405.875 | [88.0191,1875.577] | 1.6054e-39 |
| BMIgroup | <=35 | 48 | 76.19% | 154 | 79.79% | 1 |  |  |
| 35+ | 15 | 23.81% | 39 | 20.21% | 1.23404 | [0.6265,2.4306] | 0.5943 |
| RACE | White | 56 | 88.89% | 181 | 93.78% | 1 |  |  |
| Non-white | 7 | 11.11% | 12 | 6.21% | 1.8854 | [0.7082,5.0193] | 0.2652 |
| COPD | No | 54 | 85.71% | 175 | 90.67% | 1 |  |  |
| Yes | 9 | 14.29% | 18 | 9.33% | 1.6204 | [0.68823.8152] | 1 |
| Destination post-op | No | 61 | 96.83% | 186 | 96.37% | 1 |  |  |
| Yes | 2 | 3.17% | 7 | 3.63% | 0.8712 | [0.1763,4.3058] | 0.8658 |
| BMI |  | 30.648 | 6.756 | 30.698 | 7.038 | 30.632 | 6.681 | 0.9462 |
| AGE |  | 50.453 | 9.985 | 51.413 | 10.932 | 50.140 | 9.667 | 0.3807 |
| Delta VAS |  | 1.624 | 2.996 | 1.651 | 2.891 | 1.615 | 3.037 | 0.9339 |
| Pre-op VAS |  | 6.153 | 2.606 | 6.349 | 2.528 | 6.089 | 2.634 | 0.4920 |
| Post-op VAS |  | 4.461 | 3.135 | 4.635 | 3.249 | 4.404 | 3.103 | 0.6128 |
| Median Income |  | 45787.54 | 10481.05 | 47020.10 | 8785.54 | 45398.66 | 10954.24 | 0.3011 |

## **Multivariate Analysis**

A stepwise multivariate logistic regression was conducted on the data set with 243 observations and Table 3 shows the estimates of coefficients. Readmission was modeled as response, the variables of risk factors were included in the full model and dropped based on VIF value. Stepwise logistic regression was applied, and the final model was chosen by AIC. Based on a 0.05 significance level, implant loosing, adjacent segment disease, and pseduoarthrosis are significant predictors of readmission. Figure 1 shows the ROC of the final model and the AUC is 0.8242 with a 95% confidence interval being [0.7572, 0.8913].

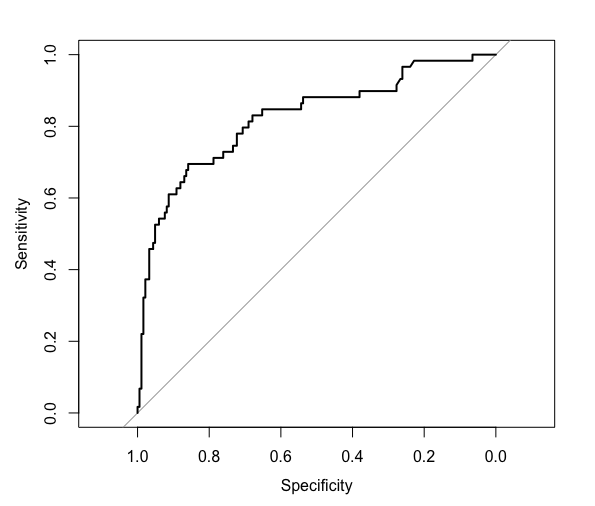


Figure 1. ROC curve of the final model

Table 3. Coefficient of Logistic Regression

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| coefficient | Odds | Estimate | Std.Error | z value | p-value | Association type |
| Intercept | 0.01289 | -4.3515 | 1.3231 | -3.289 | 0.001 |  |
| Implant Loosing | 12.7541 | 2.5459 | 0.5561 | 4.578 | 4.69e-6 | Positive |
| Adjacent segment disease | 9.2432 | 2.2239 | 0.5517 | 4.031 | 5.557e-5 | Positive |
| pseduoarthrosis | 7.5436 | 2.0207 | 0.5667 | 3.565 | 3.63e-4 | Positive |
| Median Income | 1 | 2.998e-5 | 1.746e-5 | 1.717 | 0.086 | Positive |
| BMI | 1.0422 | 0.0413 | 0.0268 | 1.541 | 0.1232 | Positive |
| Sex | 0.5754 | -0.5527 | 0.3750 | -1.474 | 0.1405 | Negative |

According to confusion table, the misclassification rate and the power the prediction are highly related to the cutoff setting. Because of the definition of variables, the cutoff point of common used and Youden’s Index are 0.5 and 0.2091. To maximize detection of any readmission and minimize type I error, the cutoff point are set as 0.065 and 0.96. For these four cutoff points, the misclassification rates are 0.1564, 0.1811, 0.7160 and 0.2387 respectively.

Table 4. Confusion matrix at different cutoffs of regular logistic regression

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| cutoff=0.5 (common used) | predict | response | | Sensitivity | Specificity | Type I error | Type II error |
| 1 | 0 |
| 1 | 31 | 10 | 0.5254237 | 0.9456522 | 0.05434783 | 0.4745763 |
| 0 | 28 | 174 |
| cutoff=0.2091 (Youden's Index) | predict | response | | Sensitivity | Specificity | Type I error | Type II error |
| 1 | 0 |
| 1 | 41 | 26 | 0.6949153 | 0.8586957 | 0.1413.43 | 0.3050847 |
| 0 | 18 | 158 |
| cutoff=0.065  (maximize detection of any readmission) | predict | response | | Sensitivity | Specificity | Type I error | Type II error |
| 1 | 0 |
| 1 | 59 | 174 | 1 | 0.05434783 | 0.9456522 | 0 |
| 0 | 0 | 10 |
| cutoff=0.96 (minimize type I error) | predict | response | | Sensitivity | Specificity | Type I error | Type II error |
| 1 | 0 |
| 1 | 1 | 0 | 0.01694915 | 1 | 0 | 0.9830508 |
| 0 | 58 | 184 |

## **Results and Discussion**

Table 5 shows the comparison between univariate analysis and multivariate analysis for readmission. Both of univariate and multivariate analysis show significant for implant loosing, pseduoarthrosis, and adjacent segment disease.

Table 5 Comparison between univariate analysis and multivariate analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Risk factor | significance | |
| Univariate | Multivariate |
| Sex | female | non-significant | non-significant |
| Insurance | Medi care or medi care + medic aid | non-significant | non-significant |
|  | Medic aid | non-significant | non-significant |
|  | Self-pay | non-significant | non-significant |
| Diabetes | Yes | non-significant | non-significant |
| Smoking | Yes | non-significant | non-significant |
| ASA class | more than severe disturb (3,4,5) | non-significant | non-significant |
| AGE (cont.) |  | non-significant | non-significant |
| BMI (cont.) |  | non-significant | non-significant |
| Preop VAS (cont.) |  | non-significant | non-significant |
| Postop VAS (cont.) |  | non-significant | non-significant |
| Delta VAS (cont.) |  | non-significant | non-significant |
| Median income (cont.) |  | non-significant | non-significant |
| Hypertension | Yes | non-significant | non-significant |
| Implant loosening | Yes | significant | significant |
| Implant brakeage | Yes | non-significant | non-significant |
| Comorbidities | Yes | non-significant | non-significant |
| pseduoarthrosis | Yes | significant | significant |
| Adjacent segment disease | Yes | significant | significant |
| Proximal junctional fracture | Yes | non-significant | non-significant |
| Destination post-op | Yes | non-significant | non-significant |
| Revision surgeries | Yes | significant | non-significant |
| RACE | non-white | non-significant | non-significant |
| COPD | Yes | non-significant | non-significant |

1. This part was cited from [here](https://www.cdc.gov/nchs/nhis/index.htm). [↑](#footnote-ref-1)