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.

1. 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		0.1019
	female	157	61.33%	142	59.92%	15	78.95%	2.5088	[0.8079, 7.7906]	

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

2. 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

3. 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].

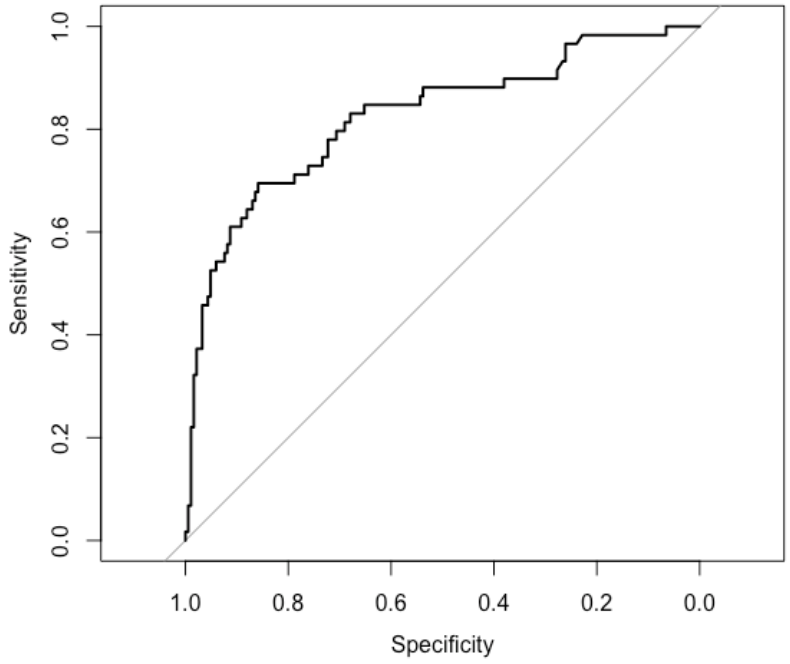

Figure 1. ROC curve of the final model

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 1	0	Sensitivity	Specificity	Type I error	Type II error
	1	31	10	0.5254237	0.9456522	0.05434783	0.4745763
	0	28	174				
cutoff=0.2091 (Youden's Index)	predict	response 1	0	Sensitivity	Specificity	Type I error	Type II error
	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 1	0	Sensitivity	Specificity	Type I error	Type II error
	1	59	174	1	0.05434783	0.9456522	0
	0	0	10				
cutoff=0.96 (minimize type I error)	predict	response 1	0	Sensitivity	Specificity	Type I error	Type II error
	1	1	0	0.01694915	1	0	0.9830508
	0	58	184				

4. 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