Title
Predicting Post-Surgical Outcomes in Patients with Spinal Cord Compression

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Predicting Post-Surgical Outcomes for Patients with Spinal Cord Compression

A thesis submitted in partial satisfaction of the requirements

for the degree Master of Science in Clinical Research

by

Laurie O'Connor

2017

ABSTRACT OF THE THESIS

Predicting Post-Surgical Outcomes for Patients with Spinal Cord Compression

by

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Master of Science in Clinical Research

University of California, Los Angeles, 2017

Professor Marc Adam Suchard, Chair

Background: Spinal cord compression may lead to numerous symptoms and decreased functional capabilities. Causes include spinal stenosis, herniated disks, tumors, and spinal cord injury. Surgical outcomes are difficult to predict, especially those related to changes in patient functional capabilities. In this study, we sought to: 1) determine the predictors of change in disability and pain for spinal surgery patients, and 2) evaluate the relationship between pain and disability outcomes.

Methods: A single arm, 24-month cohort, repeated measures study of spinal surgery patient outcomes was performed in adult patients with spinal cord compression for which a surgical procedure was performed between June 2013 and December 2015, and with at least six months post-surgery data (N=76). Using linear regression, clinical and demographic parameters were

evaluated as predictors of reduction in functional disability and pain, as measured by Oswestry Disability Index (ODI) and Visual Analog Scale (VAS) for Pain, respectively. The interaction between change in pain and functional disability was also evaluated.

Results: Changes from baseline were significant ($p<0.05$) for both the Oswestry Disability Index score (-0.13, 0.086-0.178), and Visual Analog Scale for Pain (-0.20, 0.129-0.268). Significant predictors for reduction in pain were pre-surgery pain and disability, prior spinal surgery history, age, alcoholic consumption, and microdiscectomy intervention. Predictors for reduction in disability were pre-surgery pain and disability, duration of symptoms, weight, resection, instrumentation, and laminectomy. Additionally, reduction in pain was found to be a significant confounder (>10% change in effect estimate with and without confounder) in the analysis, strongly affecting the impact of some predictors.

Conclusions: The results of this study suggest that postsurgical reduction in pain may be more amenable to prediction than reduction in disability. In addition, the relationship between spinal surgery disability and pain outcomes may be one of the factors that make prediction of surgical outcomes difficult. We recommend that future research, seeking to identify predictors of spinal surgery outcomes, be carefully designed to take into account the impact of pain on disability.

The thesis of Laurie O'Connor is approved.

Ning Li

Daniel C. Lu

Marc Adam Suchard, Committee Chair

University of California, Los Angeles

2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 MANUSCRIPT

1.1 Introduction

Spinal cord compression, where the spinal cord undergoes compression due to an external pressure source, may lead to numerous symptoms and decreased functional capabilities. The causes of spinal cord compression are diverse, and may include spinal stenosis, herniated disks, and other conditions, such as tumors [1]. Lumbar spinal cord compression of the lumbar vertebra caused by disk degeneration, may lead to pain, weakness, numbness and difficulties in walking. Cervical spondylotic myelopathy similarly affects the upper extremities. Herniated disks, caused by injury, weakness, or degeneration, may apply pressure to the spinal column, resulting in pain, weakness, and disability [1]. Other causes of spinal cord compression include spinal injury and tumors.

The incidence and prevalence of spinal cord compression are unknown and difficult to determine, as there are a variety of causes, the prevalence of many causes is unknown, and many cases may be undiagnosed. Estimates have been made for prevalence of lumbar spinal stenosis compression (8-11%) for cervical spondylotic myelopathy (8-12%), and for herniated disk (1-3%) [2]. While these are diverse causes, the common underlying or root cause of symptoms and pain experienced by patients is the compression of the spinal cord, with the accompanying ischemia and reduction in signal transmission [3][4][5][6].

Surgical approaches are often used to remove the source of spinal cord compression. The

determination of surgical procedures to be applied depends upon the extent, location, and the diagnosed source of compression, as well as the medical history and needs of the patient. Examples of surgical methods that address spinal cord compression include decompression, laminectomy, discectomy, arthrodesis (fusion), resection, and insertion of stabilizing instrumentation. Each of these includes a variety of approaches, and a single surgical event may include multiple procedures [7].

Removal of the source of spinal compression may not be entirely successful in relieving the disability, pain or other problems caused by the original compression, as the patient may have experienced irreversible changes in nerve connections or signaling pathways. Patients may also learn conditioned pain responses that do not recede when the source of pain is removed. Anticipation of pain may lead patients to avoid certain movements or activities, thus contributing to the patient's perception of disabilities. For these and other reasons, surgical outcomes are difficult to predict, especially those related to changes in patient functional capabilities. [8]

Surgical outcomes for spinal cord surgery may be measured by several factors including medical tests, validated questionnaires for measuring pain and disability, and functional tests for strength and dexterity, such as manual tracking, and gait. Validated surveys, such as ODI (Oswestry Disability Index) [9] and VAS (Back Pain Visual Analogue Scale) [10], have often been utilized to assess patient outcomes. However, these are self-reported outcomes, and do not, by themselves, objectively measure patient functional outcome indicators, such as gait or the ability to control hand grip strength or timing. Objective measures of disability have been obtained through the use of instrumented shoes and hand-grip measurement devices that assess functional

characteristics such as hand-grip strength and timing, foot-floor reaction, floor dwell time, and gait length, by interpreting physical data such as time, distance, pressure, acceleration, and velocity [11],[12],[13],[14].

Objective measures, used in combination with validated surveys, may provide more accurate and repeatable assessment of patient functional capabilities and may make it possible to identify factors that are predictors of patient post-surgical functional outcomes [15]. However, the use of these devices for measurement of disability is still in an exploratory stage, and is subject to errors in calibration, poorly understood inter-patient, and inter-instrument variability, non-standardized interpretation of results, as well as the unreliability and limited availability of such measurement devices.

The Oswestry Disability Index has been in use for over 20 years as a measure of disability. It has been shown to have good construct validity, good internal consistency, high test/re-test reliability and responsiveness, and a low burden of administration [16]. It has been used across a variety of spinal cord related conditions. It has been widely used as an indicator of patient disability in a health or disability insurance setting [17]. Similarly, the Visual Analog Scale for Pain has a proven track record of reliably measuring the patient's experience of pain and its impact on daily activities [18].

The Minimum Clinically Important Difference (MCID) for ODI and VAS have been set by the FDA for some procedures, for example, for lumbar spinal surgery, a MCID of ODI=10, and VAS=15. However, there is a great diversity of opinions and approaches, ranging from an ODI

MCID of 4 to 15. Some claim that MCID may vary by patient population characteristics (e.g. children or diagnosis category) or by severity of initial pain or disability. Others claim that MCID should be evaluated as a function of the risk of a surgical procedure [19].

Many studies which have been performed to determine the efficacy of spinal surgery [20][21][23] [24][25] focus on a specific indication or procedure, attempting to predict surgical outcomes in a narrowly defined set of patients. Predictors of disability identified include pre-surgical disability and duration of symptoms prior to surgery. However, results are not always compelling and may be sometimes conflicting, depending upon research design, especially when long-term outcomes are considered [25].

If pain has an influence on disability, then it is not unreasonable to hypothesize that change in pain has an influence on change in disability. But the relationship between change in pain and change in disability has not been quantified for patients diagnosed with spinal cord compression. The relationship between pain and disability has been explored in some dimensions, for example, it is subject of studies that seek to determine which measure (e.g., ODI or VAS) is a better indicator of specific characteristics [26], and studies have been performed to identify the impact of pain on functional capabilities [27] [28]. However, many published studies do not take into consideration the post surgery change in pain when interpreting postsurgical change in disability. There appears to be no generally accepted methodology for interpreting the impact of pain (or pain management strategies) on disability outcomes, in the context of spinal cord surgery aimed at relieving spinal cord compression.

The objective of the research is to evaluate pre- and post- surgical data in patients with spinal cord compression, diagnosed with lumbar spinal stenosis, cervical spinal myelopathy, or other sources of spinal cord compression, to determine predictors for success of surgical treatment, and to evaluate the impact of change in pain on change in disability. The proposed work includes an initial assessment of a patient database for predictors of surgical success that may be determined using only the ODI and VAS surveys in conjunction with the patient characteristics data.

In this study, we sought to 1) determine predictors of change in disability as measured by the Oswestry Disability Index (ODI), 2) determine predictors of change in pain as measured by the Visual Analog Scale (VAS) for Pain, and 3) Determine the relationship between change in pain and change in disability for patients with spinal surgery.

1.2 Methods

STUDY DESIGN

A study of spinal surgery patient outcomes was performed in adult patients with spinal cord compression for which a surgical procedure was performed between June 2013 and December 2015. This was a single arm, 24-month cohort study of 76 subjects conducted at a single location, University of California at Los Angeles (UCLA). Eligibility criteria were age of at least 18 years old, with diagnosis of spinal stenosis, herniated disc, or other condition, such as tumor, resulting in compression of the spinal cord. Post-surgical follow-up was planned at one week, one month, and every three months through twenty-four months. Patients selected for the study were those with both pre-surgical baseline disability and post surgical disability outcome data of at least six months.

CLINICAL DATA COLLECTION

Study enrollment included prescreening and an informed, written consent. Initial patient visit data included a medical information sheet containing a general health state questionnaire, and validated survey questions relating to pain and disability. At each follow-up visit, patients were administered the surveys. After each follow-up visit, the survey results were evaluated and recorded in a structured electronic file format. An IRB-approved patient database of spinal surgery recipients was created which includes pre- and post- surgical data. This data includes preoperative and postoperative patient surveys, treatment dates and types, patient characteristics, and significant prior medical history including baseline medications.

ODI and VAS scores were calculated based upon answers to the standard questionnaires administered by study staff. ODI scores were computed using a standardized method for ODI, with a 100 point maximum, normalized to a one point maximum. VAS scores, for which there is no standard method of combination, were represented as a composite endpoint of four equally weighted dimensions – current pain intensity, pain, mood, and the extent to which pain had an adverse effect on desired activities during the last month. The selected questions did not address pain medication levels. In order to minimize variation, only two different scorers were utilized for the ODI and VAS data.

Independent variables data included demographics, medical and medication histories, as well as other health-related factors such as smoking and consumption of alcohol. Medical history relevant to the study included diagnosis category (herniated disc, spinal stenosis, other), duration

of pain in back and leg or arms, pre-surgical pain, prior spinal surgery, and the use of pain medications. Affected regions (i.e., thoracic, cervical, lumbar) were recorded as well as initial and final vertebral levels, and surgical interventions.

Surgical intervention data was collected from the patient record. Subjects were treated with one or more interventions. Surgical interventions were mapped onto a defined set of categories: decompression, laminectomy, discectomy, arthrodesis (fusion), instrumentation, and resection. Information on location (region, vertebral level start and end position) and extent (number of levels, number of procedures) was also recorded. Derived factors, representing extent of intervention, included number of levels, and number of interventions.

OUTCOMES

The primary outcome of interest was the predictors of post-surgery change in disability, as measured by ODI. Secondary outcomes of interest were:

1) predictors of post-surgery change in pain, as measured by VAS, and
2) relationships between change in pain (VAS) and change in disability (ODI).

The relationship between the available patients and those in the original cohort were also investigated to determine if the patient set was representative of the overall cohort.

DATA ANALYSIS

An analysis of outcomes for patients with at least six months post-surgery data was completed (N=76). All analyses were performed in RStudio, using the R statistical package. Summary statistics for baseline characteristics were computed for the patients selected for the study.

Patients without baseline or a minimum of 6 months post-surgical data were eliminated. The number of patients selected for the study, 76, was substantially lower than the number of potential subjects originally identified. Consequently, a determination was made as to whether the selected set of subjects was representative of the original population. Following a visual inspection of the data, the method of testing whether these two groups were similar in several dimensions, was logistic regression. The original 386 patients with baseline data were coded as either selected or not selected, and logistic regression was used to determine whether there were "predictors of selection for the study. A p-value of <0.05 was considered statistically significant.

Statistical analyses of the primary and secondary outcomes were performed to determine if there was a significant difference between pre- and post- surgical outcomes. Dependent variables were tested for normality; paired t-tests were used to determine significance of the difference in means, and the Wilcoxon rank sum test applied.

Correlations between continuous predictors were evaluated by examining Pearson's correlation coefficient for all continuous variables, and significance determined. The relationship between reduction in disability and reduction in pain was investigated through the construction of a linear regression model, which was tested for significance and for normality of residuals with the Shapiro-Wilks test for normality.

Univariate linear regression was used to identify potential significant ($p<0.20$) factors that are predictive of change in the primary and secondary outcomes. Interactions were evaluated in the univariate model, and marked as candidates for inclusion in the multiple variable regression

model if statistically significant. Magnitude and significance of predictors were re-examined with the inclusion of variables that were correlated with the independent and dependent variables, to identify potential confounders. Variables were identified as confounders if there were changes of at least 10% change in effect estimate with and without confounder for the variable under investigation.

A linear multiple regression model was constructed for each outcome, iteratively adding in variables. Candidate models were evaluated for significance, for percent of variation explained by the model (R-squared), and for normality of residuals.

1.3 Results

Cohort Characteristics

There were 533 surgical patients during the period of the study; 461 for which there was primary outcome data at either baseline or one week post-surgery, and 386 with pre-surgical baseline outcome data. There were 123 patients with baseline and at least three months follow-up data. As detailed in the Methods section, any patient with less than six months data was excluded, therefore, the 76 patients with baseline and at least 6 months follow-up data were included in the study.

Table 1 summarizes the baseline characteristics. In the selected cohort, the mean patient age was 59.7 and the median was 59. The age of the youngest patient was 30, and the oldest was 87. The mean height, weight, and BMI were 66 inches, 165 pounds, and 25.74, respectively. The majority of the patients were male (55%), and of white ethnicity (68%). Only 8% admitted to

smoking, and 24% admitted to consumption of alcoholic beverages.

In the selected cohort, diagnoses were divided between spinal stenosis (26%), herniated disk (25%), other known, such as tumor (21%), and unknown (28%). 30% of the patients had prior spinal surgery history. At the pre-surgery interview, 61% were currently taking a medication for pain, 47% of the patients had back symptom duration of 12 months or more, and 17% of patients had leg or arm symptom duration of 12 months or more.

Figure 1 shows a comparison of characteristics for the entire cohort and for the subset identified for the study. While many of the variables were similar in mean or proportion, there were some differences. A logistic regression model identified two predictors of selection: white ethnicity and alcoholic consumption, although the effect size was small.

Distribution of outcome measures

The distributions for pain and disability shifted to the left after surgical intervention, indicating an improvement in post-surgery ODI and VAS. The distribution of the two outcome measures, change in pain (V.delta) and change in disability (O.delta) were visually inspected and tested for normality. The Shapiro-Wilk normality test indicated ($p<0.05$) that for O.delta and V.delta this sample is not from a normally distributed population.

The planned analysis to test the difference in means was a paired t-test, which is based upon the assumption that data is normally distributed, but which is robust to minor deviations from normality. A visual inspection of the distributions of ODI and VAS indicated this is the case, as

there was no extreme skew or bimodal shape. T-tests results, as shown in Figure 2, indicate that the difference in the means, pre- and post-surgery, for ODI is 0.13 (0.086-0.178), for VAS is 0.20 (0.129-0.268). A Wilcoxon Signed Rank Test, which has a greater power than the t-test for non-normally distributed data, indicated that the true location shift of the mean is not equal to zero.

Correlation between study variables

Pearson's tests for correlation indicate significant ($p<0.05$) correlation between several pairs of study variables, including baseline and post-surgery disability (0.76), baseline and post-surgery pain (0.45), reduction in pain and reduction in disability (0.32), baseline pain and reduction in pain (0.46), and baseline pain and post-surgery disability (0.48) and baseline disability and reduction in disability (0.29).

Univariate linear regression

Univariate linear regression models for O.delta and V.delta were constructed and examined to determine significant predictors. Table 2 provides a summary of the univariate reduction models with their effect size and p-value. Figure 3 describes and plots univariate models for reduction in disability versus baseline disability, and reduction in pain versus baseline pain. In the univariate models, a significant relationship was found between physician and the outcomes; however an examination of differences in procedures, diagnoses, and baseline values showed significant differences in the patient profiles for the two physicians. Univariate models yielded some associations with few predictors with significance ($p<0.20$)

Multiple linear regression

The univariate analyses were rerun with inclusion of correlated predictors in the univariate linear regression models, identifying a larger set of possible predictors. A multiple linear regression model was constructed for reduction in pain (V.delta) and for reduction in disability (O.delta), with correlated variables included in the model. Although the models explain only 70% and 47 % of the data variability, respectively, the models show significance ($p<0.05$) and tested positive for normally distributed residuals. A second model of O.delta was constructed with reduction in pain (V.delta) as a covariate, resulting in a model that explained 63% of the variation in O.delta. Table 2 is a summary of the univariate and multiple linear regression predictors found.

The Multiple Linear Regression models indicate that post-surgery reduction in pain (V.delta) is a function of baseline disability (-), baseline pain (+), prior spinal surgery history (-), age above median (+), length of back symptoms (-), alcoholic consumption (-), and no microdiscectomy intervention (-). The Multiple Linear Regression model indicate post-surgery reduction in disability (O.delta) is a function of baseline disability (+), baseline pain (+), instrumentation (-), back symptoms <= 12 months (+), weight above median (+), resection (+), and laminectomy(-).

Reduction in pain (V.delta) was determined to be a confounder (>10% change in effect estimate with and without confounder) for reduction in disability (O.delta). Thus, reduction in pain explains a significant fraction of the reduction in disability. Finally, the variability originally explained by physician (MD), was explained in these new models by other independent variables, with the result that the MD contribution to the model became insignificant ($p<0.85$).

1.4 Discussion

Predictors

Changes from baseline were significant ($p<0.05$) for both the Oswestry Disability Index score (-0.13, 0.086-0.178), and Visual Analog Scale for Pain (-0.20, 0.129-0.268). Significant predictors for reduction in pain were pre-surgery pain and disability, prior spinal surgery history, age, alcoholic consumption, and microdiscectomy intervention. Predictors for reduction in disability, excluding change in pain, were pre-surgery pain and disability, duration of symptoms, weight, resection, instrumentation, and laminectomy. Additionally, reduction in pain was found to be a significant confounder (>10% change in effect estimate with and without confounder) in the analysis, strongly affecting the impact of some predictors.

Impact of pain on disability

The addition of reduction in pain to the model for O.delta resulted in large percentage changes in regression coefficients and order-of-magnitude changes in p-values for selected predictors. While some predictors lost their significance, others became more important as indicated by either magnitude, and or p-value. Thus, while change in pain, which is not a baseline value, may not be a predictor of change in disability, it may contribute towards explaining the variation for change in disability for spinal surgery patients.

Conclusions

The results of this study suggest that when improvements in ODI are to be used as evidence of spinal surgery outcomes, change in pain should also be considered to be an important factor in

interpreting results. Predictors of improvement in disability should be interpreted in light of the effect that pain has on disability.

Strengths and Limitations

A strength of this study is the focus on the relationship of change in pain to change in disability. This was made possible by the repeated measurement of pain and disability at the same time, in the same setting, using widely accepted validated survey instruments. Another strength is the limitation of the patient population to two spinal surgeons, thus reducing variability within the surgical procedures that were performed.

There were several limitations to this study. The study included a variety of diagnoses and procedures, and did not take into account the type or dosage of pain medication pre- and post-surgery. The study focused on self-reported outcomes, and consequently there were no objective measures of disability; it was not possible to determine actual physical limitations versus perceived limitations due to pain. Although a longer term look at the data may make it possible to assess changes in pain or disability over time, this study did not attempt to do so.

Future Directions

This study suggests other areas for further research, including:

- Continuation of this study to include patients who were not eligible due to length of time of follow-up after surgery, and examine the effect over time of surgery on measures of pain and disability.
- Research designed to quantify the effect of pain on disability related to spinal cord

compression

- Research to determine whether there are correlations between spinal compression indicators (physical measurements), and other measures of pain and disability, pre- and post- surgery.
- Inclusion of other logistic or economic factors such a distance of clinic from home, or medical insurance coverage, to determine if there is an effect on types of patients lost to follow-up.

TABLES AND FIGURES

Table 1. Subject Characteristics

Subject Characteristics

Table 1. Patient Characteristics

PATIENT CHARACTERISTICS	MEAN	SD	Min	Q1	Med	Q3	Max
Continuous Variables							
Age (years)	59.7	13.7	30	51	59	70.5	87
Height (inches)	57	4.1	57	63.9	66	70	75
Weight (lbs)	176.4	48.3	110	141	165	330	198.5
Pre-surgery pain (VAS)	0.56	0.23	0	0.45	0.6	0.72	0.96
Pre-surgery disability (ODI)	0.42	0.21	0	0.27	0.43	0.58	0.84

Categorical Variables	Number	Percent	**Categorical Variables**	Number	Percent
Gender			Region		
Male	42	55%	Cervical	22	29%
Female	35	46%	Thoracic	5	7%
Smoke	6	8%	Lumbar	48	63%
Drink	18	24%	Other	1	1%
Ethnicity white	52	68%	Number of levels		
Diagnosis			<=2	44	58%
Spinal Stenosis	20	26%	>=3	26	34%
Herniated Disk	18	24%	Pain duration (back)		
Other	16	21%	>=12 months	36	47%
Prior spinal surgical history	23	30%	<=12 months	39	51%
Pain Medication	46	61%	Pain duration (leg/arm)		
			>=12 months	13	17%
			<=12 months	62	82%

Table 2. Linear Regression Coefficients for V.delta, O.delta

	Change in Pain (V.delta)				Change in Disability (O.delta)					
Predictors	Uni-variate	(P< x)	Model	(P< x)	Univariate	(P< x)	Model1	(P< x)	Model2 V.delta added	(P< x)
			R-sq=0.70				R-sq=0.47		R-sq=0.63	
O.Pre*	-0.03	0.86	-0.97	<<0.01	0.32	0.002	0.23	0.07	0.53	0.0002
V.Pre*	0.49	0.006	1.29	<<0.01	0.25	0.02	0.13	0.3	-0.33	0.03
V.Delta*	<NA>	<NA>	<NA>	<NA>	0.35	0.0004	<NA>	<NA>	0.43	<<0.001
Prior Spinal Surgery History*	0.07	0.36	-0.12	0.07	-0.01	0.83				
Symptoms (back) <= 12 months*	0.02	0.75	-0.001	0.02	0.08	0.11	0.1	0.02	0.09	0.02
BMI	0.06	0.91			0.004	0.17				
WeightM	0.02	0.76			0.0002	0.69	0.15	0.02	0.24	0.008
Height	-0.01	0.39			-0.01	0.1				
AgeM	0.03	0.67	0.14		-0.05	0.237				
Ethnicity White	0.2	0.03			0.07	0.27				
Instrumentation intervention (yes)*	-0.12	0.15			-0.13	0.02	-0.1	0.07	-0.08	0.07
Laminectomy intervention (no)*	-0.05	0.47			0.07	0.15	0.14	0.003	0.15	<<0.001
Resection intervention (yes)*	0.03	0.89			0.08	0.237	0.28	0.001	0.24	0.008
MicroDiscectomy intervention (no)*	-0.08	0.38	-0.13	0.19	-0.12	0.07				
Discectomy intervention (no)	-0.04	0.61			-0.06	0.228				
Decompression intervention (no)	0.06	0.46			-0.002	0.97				
Arthrodesis intervention (no)	0.07	0.51			0.005	0.93				
Drink*	-0.07	0.4	-0.13	0.03	-0.03	0.55				
Smoke	-0.14	0.28			-0.04	0.71				
DiagCatX Other	-0.06	0.55			-0.09	0.21				
INVnX	0.02	0.77			-0.01	0.84				
nLevX <=2	0.11	0.13			0.03	0.587				
Symptoms (Neck) X	0.07	0.43			0.07	0.29				
PainTX	0.03	0.67			0.05	0.35				
Gender	0.04	0.07			0.004	0.38				

Figure 1. Study population characteristics

Selected subjects demographics are representative

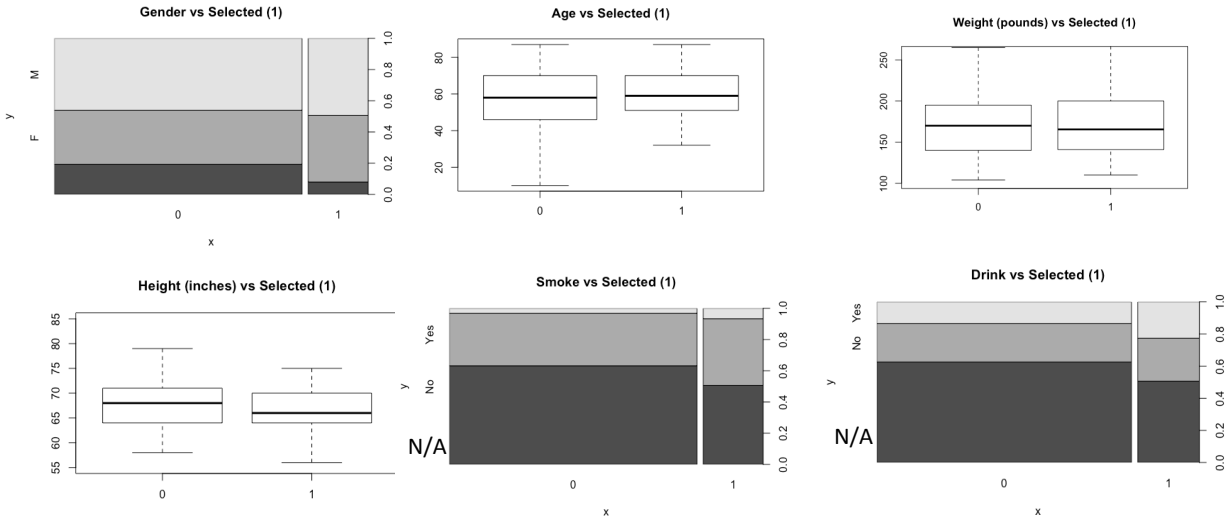
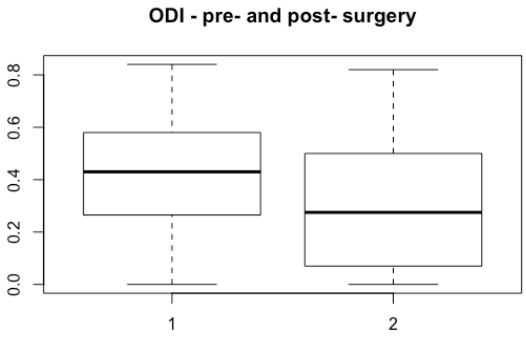
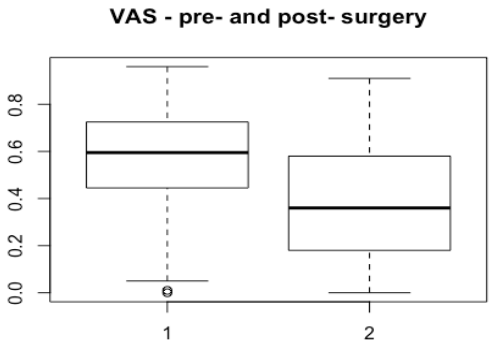


Figure 2. Pre and post surgical outcomes



Paired t-test
O.Pre and O.post

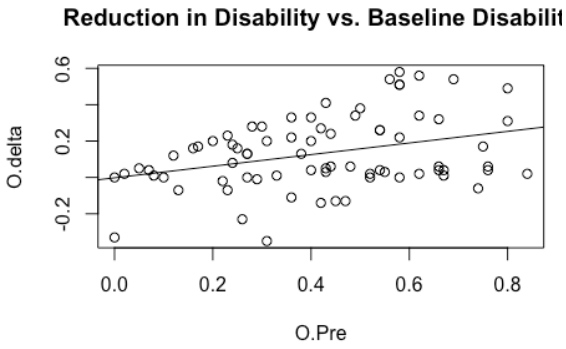
Mean = 0.132 (0.086-0.178)
95 percent confidence interval



Paired t-test
V.Pre and V.post

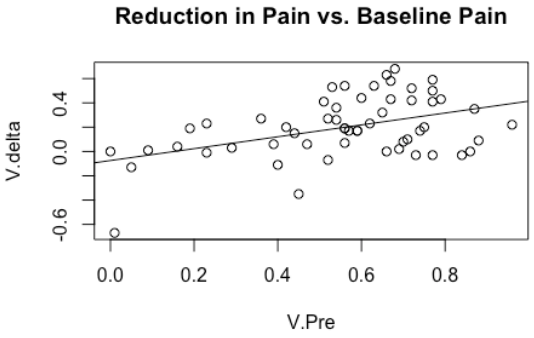
Mean = 0.198 (0.129-0.268)
95 percent confidence interval

Figure 3. Baseline disability and pain are predictors



Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.002167	0.048302	-0.045	0.96435
O.Pre	0.319316	0.102756	3.108	0.00269



Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.07441	0.08092	-0.920	0.36190
V.Pre	0.48885	0.13448	3.635	0.00062

CHAPTER 2 STATISTICAL APPENDIX

This chapter provides additional depth of discussion for the statistical analysis and explains key decisions that were made and why.

Consideration 1: Evaluation of distributions

Distributions of variables for both independent and independent variables were examined early in the data analysis process (Figures 4 and 5) in order to determine whether the planned statistical analyses were applicable to the actual data. While the distributions of the dependent variables were not strictly normal, they did not deviate from normality to the extent that they would invalidate the planned tests.

Consideration 2: Associations versus predictors

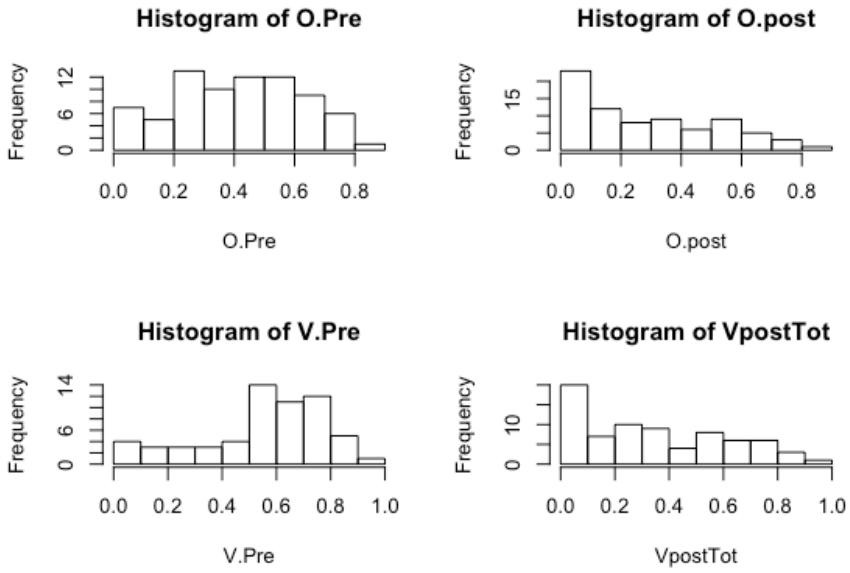
Some associations that were originally identified as candidates as for predictors were not ultimately included in the linear regression models. For example, while there was originally a strong association between MD and the pain and disability outcomes, the variability originally explained by MD, was ultimately explained by other factors

Consideration 3. Use of reduction in pain in a multiple regression model, not for prediction, but for explanation of variation

Reduction in pain was not originally considered as a predictor for reduction in disability because it is not available prior to surgical interventions. However, in the construction of the regression model, it was explored as a covariate in the regression model due to its correlation with the

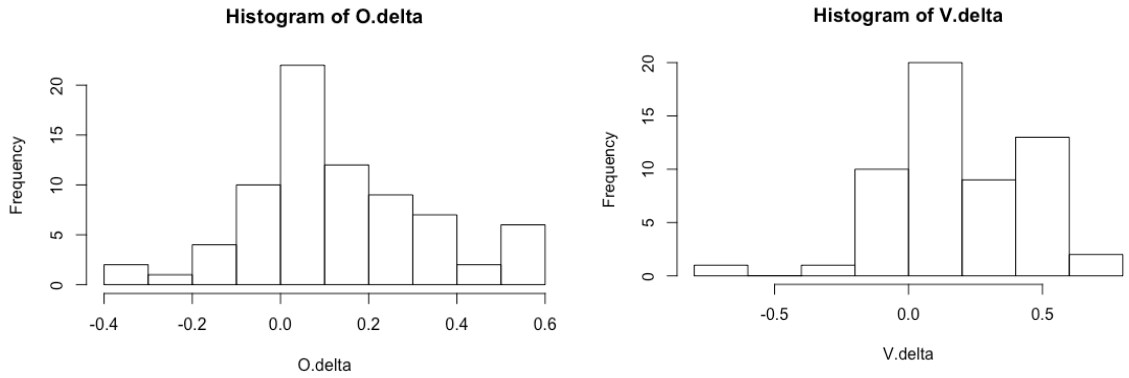
outcomes. While it cannot be used as a pre-surgical predictor, it was identified as being explanatory of a significant fraction of the variation of the outcome, change in disability, O.delta.

Figure 4. Distribution of Dependent Variables



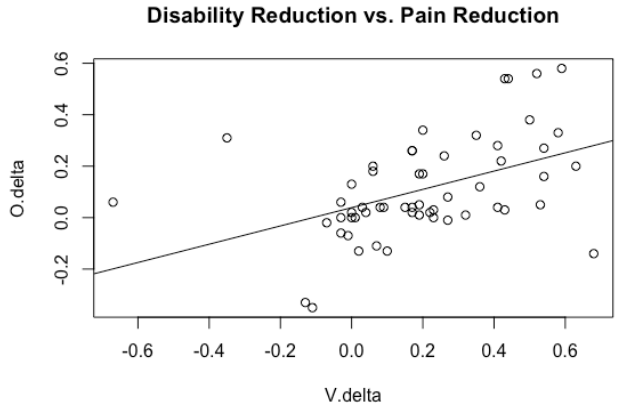
Shapiro-Wilk normality test – only O.Pre is normally distributed

Figure 5. Distribution of Outcomes



Shapiro-Wilk normality test.
Null hypothesis: Sample is from normally distributed population
Result: p-value < 0.05 → Sample is NOT from normally distributed population
data: O.delta, W = 0.9631, p-value = 0.02785
data: V.delta, W = 0.95715, p-value = 0.04486

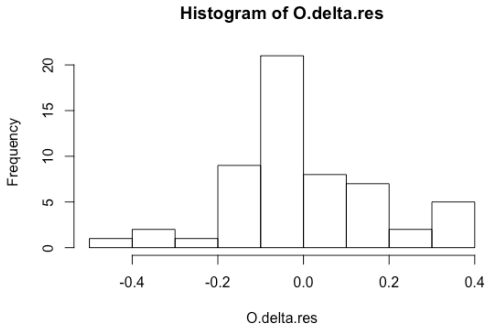
Figure 6. Relationship of Reduction in ODI and Reduction in VAS



O.delta ~ V.delta)

Linear Regression Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.03875	0.02978	1.301	0.198766
V.delta	0.35528	0.09335	3.806	0.000362



Shapiro-Wilk normality test of model residuals
O.delta.res, W = 0.96513, p-value = 0.1048
P-value > 0.05, Normally distributed → valid model

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