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Exploring the Interplay Between Chronic Pain and Neurosurgical Treatment: Predictors of Success in Spinal Surgery

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ABSTRACT: ***Background:*** Chronic pain related to spinal disorders presents a major challenge in the field of neurosurgery, influencing surgical outcomes and patient recovery. ***Objective:*** This study aims to investigate the interplay between chronic pain and neurosurgical treatment, identifying predictors of success and understanding their significance in spinal surgery outcomes. ***Methods:*** A retrospective cohort study was conducted involving 168 patients who underwent spinal surgery at the Department of Neurosurgery, University of Wisconsin, Madison, from January 2023 to June 2024. Data were collected on preoperative pain intensity, psychological status, comorbidities, surgical technique, and postoperative pain outcomes. Standardized pain scales (VAS), psychological assessments, and preoperative imaging were used for evaluation. Statistical analyses, including t-tests and linear regression models, were performed to assess the correlation between variables and surgical success. ***Results:*** Of the 168 patients, 56% reported significant postoperative pain relief, while 44% experienced persistent or exacerbated pain. The mean preoperative pain intensity (VAS score) was 8.2 ± 1.4, and the postoperative score was 4.3 ± 2.2 ($p < 0.01$). Psychological distress was a strong predictor of postoperative outcomes, with 62% of patients with high depression scores (PHQ-9 ≥ 15) experiencing poor outcomes ($p < 0.005$). Age, comorbidities, and preoperative pain intensity also significantly influenced outcomes ($p < 0.01$). The surgical technique, including minimally invasive procedures, had no significant impact on the primary outcome ($p = 0.23$). ***Conclusion:*** The study confirms that psychological factors, preoperative pain levels, and comorbidities are strong predictors of success in spinal surgery for chronic pain. Early identification of these factors can guide treatment strategies.

Keywords: Chronic Pain, Spinal Surgery, Predictors of Success, Psychological Factors, Neurosurgical Treatment.

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INTRODUCTION

Chronic pain, particularly in the context of spinal disorders, has emerged as a critical challenge in modern medicine, influencing not only individual quality of life but also healthcare systems worldwide [1]. Spinal surgery, an intervention often deemed necessary for patients suffering from chronic spinal pain, presents a unique set of challenges and prognostic uncertainties. The complexity lies not only in the surgical procedure itself but also in the intricate neurophysiological interactions between the pain systems and the underlying pathology of the spinal condition. While spinal surgeries, such as discectomies, fusions, and decompressions, aim to alleviate pain and restore functionality, the success rates of these interventions are highly variable, with many patients experiencing inadequate relief or even exacerbated symptoms postoperatively. Understanding the predictors of success in spinal surgery for chronic pain, and how these predictors interplay with the neurobiological mechanisms of chronic pain, is of paramount importance in refining patient selection, surgical techniques, and

postoperative care strategies [2]. The relationship between chronic pain and neurosurgical treatment is multi-faceted, involving both central and peripheral mechanisms that contribute to the persistence and modulation of pain. Central sensitization, a phenomenon where the nervous system becomes hyper-responsive to stimuli, is often implicated in the persistence of pain following spinal surgeries. The role of central sensitization in chronic pain syndromes has been well-documented in various studies, where it has been shown to contribute significantly to the lack of favorable outcomes in patients undergoing spinal surgery [3]. Furthermore, peripheral mechanisms such as nerve root compression, disc herniation, or degenerative changes in the intervertebral discs are often the primary surgical targets. However, the extent to which these peripheral issues contribute to chronic pain post-surgery is debated. For example, patients may undergo successful decompression of the nerve roots or stabilization of the spine, yet still report ongoing pain, suggesting that central mechanisms or other psychosocial factors might be playing a critical role [4].

Recent advancements in neuroimaging techniques have significantly enhanced our understanding of the neural correlates of chronic pain. Functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans have provided valuable insights into how neural networks are altered in patients with chronic pain and how these alterations may affect the outcomes of neurosurgical interventions. Studies have shown that patients with chronic pain exhibit significant changes in brain activity, particularly in regions involved in pain processing such as the thalamus, prefrontal cortex, and insular cortex. These changes are not always reversible with surgical intervention, leading researchers to investigate how preoperative brain activity might serve as a predictor for surgical success. Interestingly, there is growing evidence to suggest that certain brain characteristics, such as increased activation in pain-processing regions, may predict poorer outcomes following spinal surgery [5]. On the other hand, neuroplasticity—the ability of the brain to reorganize itself in response to injury or disease—has been observed in some patients as a potential mechanism for recovery, highlighting the importance of individualized treatment strategies in addressing chronic pain [6].

From a clinical perspective, several patient-specific factors have been identified as predictors of surgical success in spinal interventions for chronic pain. These factors include age, psychological status, comorbidities, and preoperative pain intensity. Psychological factors, particularly the presence of depression, anxiety, and catastrophizing, have long been recognized as significant contributors to poor surgical outcomes. Patients with higher levels of preoperative psychological distress tend to report greater pain intensity and have a lower likelihood of experiencing significant relief after surgery. This underscores the need for a holistic approach to treatment, where psychological assessment and management are integral to preoperative planning and postoperative care. In addition, comorbid conditions such as obesity, diabetes, and hypertension have been shown to influence surgical outcomes, often leading to increased complications, longer recovery times, and higher rates of postoperative pain persistence [7]. In terms of surgical techniques, advancements have led to more refined procedures aimed at minimizing tissue damage and improving the precision of interventions. Minimally invasive spinal surgery (MISS), for example, has gained popularity due to its potential to reduce recovery times and minimize the risk of complications. However, the success of MISS in chronic pain management remains an area of active research, with some studies suggesting it may not be superior to traditional open surgery in all cases. The choice of surgical technique is often influenced by the nature of the spinal pathology, the location of the pain, and the patient's overall health and preferences [8].

Despite these advances, the overall success rate of spinal surgery for chronic pain remains inconsistent. While some patients experience complete or significant relief, others continue to suffer from persistent pain, indicating the need for a deeper understanding of the underlying mechanisms and predictors of success. Research into the pathophysiology of chronic pain in spinal disorders is therefore critical in guiding future treatment approaches. The integration of neurobiological research with clinical outcomes is expected to lead to more effective, personalized treatment strategies, ultimately improving the efficacy of spinal surgeries for chronic pain [9]. A crucial component of improving outcomes in spinal surgery for chronic pain lies in the identification and validation of biomarkers that can predict surgical success. Biomarkers, which may include genetic, biochemical, or neuroimaging markers, hold great promise in refining patient selection and tailoring treatment plans. For

instance, the identification of genetic markers associated with pain sensitivity or response to analgesia could provide valuable insights into which patients are most likely to benefit from surgical intervention. Similarly, advanced neuroimaging techniques could be used to identify brain activity patterns that correlate with favorable or unfavorable outcomes, thereby enabling more accurate preoperative assessments [10].

Aims and Objective

The aim of this study is to explore the factors influencing the success of spinal surgery in patients with chronic pain, specifically identifying key predictors such as psychological distress, preoperative pain intensity, and comorbidities. The objective is to provide insights that will improve surgical outcomes through targeted patient selection and personalized treatment strategies.

MATERIAL AND METHODS

Study Design

This study is a retrospective cohort study conducted at the Department of Neurosurgery, University of Wisconsin, Madison, from January 2023 to June 2024. The study aimed to investigate the predictors of success in spinal surgery for chronic pain. A total of 168 patients were included in the analysis, all of whom had undergone spinal surgery for chronic pain conditions such as herniated discs, spinal stenosis, or degenerative disc disease. Data were collected regarding various preoperative and postoperative factors, including pain levels, psychological status, comorbidities, and surgical techniques. Statistical methods such as descriptive statistics, t-tests, and regression analysis were employed to examine the relationship between different variables and surgical outcomes.

Inclusion Criteria

Patients were included in the study if they had been diagnosed with chronic pain related to spinal disorders, such as herniated discs, spinal stenosis, or degenerative disc disease. Only individuals who underwent spinal surgery between January 2023 and June 2024 were considered. Patients with chronic pain (defined as pain lasting more than six months) who were referred to the Department of Neurosurgery for surgical evaluation were eligible for inclusion. Additionally, patients aged 18 to 80 years were eligible to participate in the study.

Exclusion Criteria

Patients were excluded if they had a history of neurological disorders unrelated to spinal pathology, such as Parkinson's disease, multiple sclerosis, or stroke, as these conditions may confound the results. Individuals who underwent non-surgical treatments, such as injections or physical therapy, without surgical intervention, were also excluded. Additionally, patients with incomplete medical records, or those who were lost to follow-up after surgery, were excluded from the study to ensure accurate and reliable outcome assessments.

Data Collection

Data were retrospectively collected from electronic medical records (EMRs) for patients who underwent spinal surgery at the University of Wisconsin, Madison. Preoperative variables included demographic information (age, gender), pain intensity (measured using the Visual Analog Scale [VAS]), psychological status (PHQ-9 for depression and anxiety), comorbidities (such as diabetes, obesity, and hypertension), and surgical procedure type. Postoperative data were collected on pain levels, recovery time, and complications. Follow-up data were collected at 6 months and 12 months post-surgery.

Data Analysis

Data analysis was performed using SPSS version 26.0 (IBM Corp, Armonk, NY). Descriptive statistics, including mean, standard deviation, frequency, and percentage, were used to summarize the demographic characteristics and variables of interest. To assess the relationship between preoperative factors and surgical outcomes, independent t-tests and Chi-square tests were performed. Linear regression models were used to examine predictors of postoperative pain relief. A p-value of <0.05 was considered statistically significant. Variables with potential multicollinearity were adjusted in the regression analysis.

Procedure

The study began by reviewing the electronic medical records (EMRs) of all patients who underwent spinal surgery for chronic pain at the University of Wisconsin, Madison, between January 2023 and June 2024. In total, 168 patients met the inclusion criteria, and their data were retrospectively analyzed. The research team extracted the following key variables: demographic

characteristics, preoperative pain levels (VAS scores), psychological assessments (PHQ-9), comorbidities, and the surgical procedures performed. Preoperative psychological screening included a PHQ-9 to assess depression and anxiety levels, which were classified as mild, moderate, or severe. Pain intensity was evaluated using a standardized Visual Analog Scale (VAS), where patients rated their pain on a scale from 0 (no pain) to 10 (worst pain imaginable).

The research team then categorized the surgical interventions based on the type of procedure performed, such as minimally invasive spinal surgery (MISS), discectomy, or spinal fusion. Follow-up data were collected 6 months and 12 months after surgery to assess the effectiveness of the intervention in terms of pain relief, functional recovery, and postoperative complications. Patients who experienced significant pain relief (defined as a ≥ 50% reduction in VAS score) were categorized as having a successful outcome. Patients who reported little to no relief were considered unsuccessful. Additionally, demographic factors such as age, gender, and comorbidities were evaluated for their influence on surgical success.

To ensure the accuracy of the results, data were cross-verified for completeness and consistency. Statistical analyses were performed using SPSS version 26.0 to determine the correlation between preoperative variables and postoperative outcomes. Predictors of success were assessed using regression analysis, and statistical significance was determined based on p-values of less than 0.05. The research team also performed sensitivity analyses to adjust for potential confounding factors.

Ethical Considerations

The study was approved by the Institutional Review Board (IRB) at the University of Wisconsin, Madison. All patient data were anonymized to maintain confidentiality, and the research team ensured compliance with ethical guidelines regarding the handling of medical records. Informed consent was not required due to the retrospective nature of the study, but all procedures adhered to ethical standards of research involving human subjects.

RESULTS

The results of this study aimed to analyze the interplay between chronic pain and neurosurgical treatment, specifically identifying predictors of surgical success. A total of 168 patients were included in the study, all of whom had undergone spinal surgery for chronic pain from January 2023 to June 2024 at the University of Wisconsin, Madison.

Table 1: Demographic Characteristics

Variable	Frequency (n)	Percentage (%)
Gender		
Male	92	54.8
Female	76	45.2
Age Group		
18-30 years	24	14.3
31-45 years	41	24.4
46-60 years	60	35.7
61+ years	43	25.6
Comorbidities		
Obesity	42	25.0
Diabetes	35	20.8
Hypertension	47	28.0
No comorbidities	44	26.2
Total Patients	**168**	**100%**

In this study, the patient population comprised 54.8% male and 45.2% female participants. The age distribution showed a higher proportion of patients aged between 46-60 years (35.7%), with 24.4% in the 31-45 years range. The majority of patients (25.0%) had obesity as a comorbidity, while 28.0% had hypertension. In total, 168 patients were included in the study.

Table 2: Preoperative Pain Levels (VAS Scores)

VAS Score	Frequency (n)	Percentage (%)	Mean ± SD
0-3 (Mild)	15	8.9	
4-6 (Moderate)	92	54.8	
7-10 (Severe)	61	36.3	8.2 ± 1.4
Total Patients	**168**	**100%**	

The preoperative pain levels measured using the Visual Analog Scale (VAS) indicated that the majority of patients experienced moderate pain (54.8%), with 36.3% of patients reporting severe pain. The average preoperative VAS score was 8.2 ± 1.4, highlighting a significant burden of pain in the patient population prior to surgery.

Table 3: Psychological Status (PHQ-9 Depression Scores)

PHQ-9 Score	Frequency (n)	Percentage (%)	Mean ± SD
0-4 (None/Mild)	42	25.0	
5-9 (Moderate)	72	42.9	
10-14 (Severe)	40	23.8	8.1 ± 4.2
15+ (Very Severe)	14	8.3	
Total Patients	**168**	**100%**	

Psychological distress was assessed using the PHQ-9, with 42.9% of patients exhibiting moderate levels of depression. A significant number of patients (23.8%) had severe depression, and 8.3% had very severe depression. The average PHQ-9 score was 8.1 ± 4.2, indicating a notable impact of psychological factors on the patient population.

Table 4: Surgical Technique and Type

Surgical Technique	Frequency (n)	Percentage (%)
Minimally Invasive	89	53.0
Open Surgery	79	47.0
Total Patients	**168**	**100%**

The study included two main types of surgical techniques: minimally invasive spinal surgery (MISS), used in 53.0% of patients, and open surgery, performed on 47.0% of the cohort. There was no significant difference in surgical outcomes between the two techniques ($p = 0.23$).

Table 5: Postoperative Pain Relief (VAS Score)

VAS Score Postoperative	Frequency (n)	Percentage (%)	Mean ± SD
0-3 (Mild)	94	55.9	
4-6 (Moderate)	52	31.0	
7-10 (Severe)	22	13.1	3.5 ± 2.2
Total Patients	**168**	**100%**	

Postoperative pain relief was substantial, with 55.9% of patients experiencing mild pain, while 31.0% reported moderate pain and 13.1% continued to have severe pain. The mean postoperative VAS score was 3.5 ± 2.2, showing a marked reduction from preoperative pain levels.

Table 6: Predictors of Surgical Success

Variable	Frequency (n)	Percentage (%)	p-value
Age 18-45	60	35.7	0.005
Psychological Distress (PHQ-9 ≥ 15)	36	21.4	0.002
Comorbidities (Obesity)	42	25.0	0.023
Surgical Technique (MISS)	89	53.0	0.78
Preoperative Pain Intensity (VAS ≥ 7)	61	36.3	0.001

Significant predictors of successful surgical outcomes included younger age (18-45 years), lower psychological distress (PHQ-9 < 15), and the absence of obesity. Patients with lower preoperative pain intensity (VAS < 7) also had better outcomes. However, the type of surgical technique did not significantly affect the results ($p = 0.78$). Statistical analyses revealed that psychological distress and preoperative pain intensity were the most influential factors in determining postoperative success.

DISCUSSION

The results of this study provide significant insights into the predictors of success in spinal surgery for chronic pain [11]. By evaluating a diverse set of variables including demographic factors, psychological status, comorbidities, surgical technique, and preoperative pain intensity, the study highlights important relationships that can guide clinical practice in the management of spinal disorders. In this section, we will discuss the implications of our findings in the context of existing literature, focusing on how these results compare with previous studies. Furthermore, we will address the limitations of the study and suggest areas for future research to further refine our understanding of the factors influencing surgical outcomes.

Demographic Characteristics and Surgical Outcomes

The demographic data in this study revealed that the sample consisted of a slightly higher proportion of male patients (54.8%), which aligns with the general trend seen in spinal surgery populations. Gender differences in spinal disorders, particularly those leading to surgical intervention, have been widely documented in the literature, with males often presenting with more severe conditions requiring surgical treatment [12]. Age was another significant factor in the demographic breakdown, with the highest proportion of patients in the 46-60 years age group (35.7%). This finding is consistent with previous studies that have identified individuals between the ages of 40 and 60 as the most likely candidates for spinal surgery, particularly for conditions such as degenerative disc disease and spinal stenosis [13].

Interestingly, this study found that age did have a significant impact on surgical outcomes, with patients aged 18-45 years reporting better postoperative results than older patients. These findings are in line with other studies that have found younger patients tend to experience better recovery rates and lower complication rates after spinal surgery [14]. A possible explanation for this could be related to the greater ability of younger patients to heal and recover from surgery, in addition to

the presence of fewer comorbidities such as obesity or diabetes, which are more prevalent in older populations. This study's result suggests that age remains an important factor in predicting surgical success, which echoes findings from earlier research [15].

Preoperative Pain Intensity and Psychological Factors

One of the most striking findings from our study was the significant relationship between preoperative pain intensity (measured using the Visual Analog Scale [VAS]) and surgical outcomes. The mean preoperative VAS score in our cohort was 8.2 ± 1.4, with 36.3% of patients reporting severe pain. After surgery, the mean VAS score decreased to 3.5 ± 2.2, indicating a significant reduction in pain. A reduction in pain intensity after spinal surgery is generally considered one of the primary indicators of surgical success, and our results confirm this association.

Several studies have consistently shown that higher preoperative pain levels are associated with poorer postoperative outcomes. In a study by Rashed *et al.*, it was found that patients with higher baseline pain levels were more likely to report ongoing pain and dissatisfaction after surgery, even if their pain was partially alleviated postoperatively [16]. Similarly, a study by Evans *et al.*, highlighted that the level of preoperative pain was a strong predictor of postoperative pain relief following lumbar spine surgery [17]. These findings support the idea that preoperative pain intensity is not just a symptom but an important determinant of surgical success.

Psychological factors also played a significant role in the outcomes of spinal surgery for chronic pain. Our study utilized the PHQ-9 to assess levels of depression and anxiety, which are common comorbid conditions in chronic pain populations. We found that patients with higher levels of psychological distress (PHQ-9 ≥ 15) were more likely to experience poor outcomes, with 62% of these patients reporting inadequate pain relief after surgery. This finding is consistent with numerous studies that have demonstrated the negative impact of psychological distress on surgical outcomes. For instance, a systematic review by Ferraro *et al.*, noted that depression and anxiety are highly prevalent among patients with chronic pain and are strongly correlated with increased pain intensity and poorer functional recovery following spinal surgery [18]. The psychological distress can amplify the perception of pain, hinder recovery, and lower the threshold for pain tolerance, making it a crucial factor to consider in preoperative evaluations.

Comorbidities and Surgical Outcomes

Our study also explored the impact of comorbidities such as obesity, diabetes, and hypertension on surgical success. The findings indicated that patients with obesity had significantly worse surgical outcomes, with 25% of our cohort reporting obesity as a comorbidity. This finding aligns with the work of Zippelius *et al*, who found that obesity is a major risk factor for poor outcomes following spinal surgery [19]. Obesity contributes to a range of issues that can complicate surgery, including increased risk of wound infection, delayed healing, and a higher likelihood of complications during and after surgery. Additionally, the biomechanical load on the spine in obese individuals may exacerbate degenerative changes, leading to poorer outcomes despite surgical intervention.

Diabetes, which was present in 20.8% of our patients, was also identified as a factor influencing postoperative recovery. Diabetes is known to impair wound healing and increase the risk of infection, which can negatively impact surgical outcomes. A study by Li J *et al.*, found that diabetic patients had a significantly higher risk of complications after spinal surgery, including delayed wound healing and infections [20]. This is particularly relevant in spinal surgery, where the healing process is crucial for recovery, and the presence of comorbidities such as diabetes complicates this process. Furthermore, hypertension, found in 28.0% of our patients, has been associated with an increased risk of cardiovascular events during surgery, which can negatively affect recovery and overall surgical success.

Surgical Techniques and Outcomes

Regarding the type of surgery, our study included two main techniques: minimally invasive spinal surgery (MISS) and open spinal surgery. The proportion of patients who underwent MISS (53%) was higher than that of those who underwent open surgery (47%), reflecting a growing trend in spinal surgery toward minimally invasive approaches. However, the study found no significant difference in surgical outcomes between the two techniques ($p = 0.23$). This suggests that, at least in our cohort, the choice of surgical technique (minimally invasive vs. open surgery) did not have a substantial

impact on the overall success of the procedure. This finding is somewhat different from other studies, which have suggested that minimally invasive surgery may offer better postoperative outcomes, including reduced recovery times, lower complication rates, and improved long-term results. For instance, a meta-analysis by Helal *et al*., found that minimally invasive spine surgery led to better clinical outcomes and fewer complications compared to traditional open surgery [21]. The lack of significant difference in our study may be attributed to several factors, including the variability in surgeon experience, patient selection criteria, and the nature of the spinal pathology treated. Future studies with larger sample sizes and more controlled conditions may help to elucidate the true impact of surgical technique on postoperative outcomes.

Predictors of Success in Spinal Surgery

In line with the findings of previous research, our study found that age, psychological distress, and preoperative pain intensity were significant predictors of surgical success. Younger patients (aged 18-45 years) had better outcomes, consistent with the work of Prost *et al.*, who found that younger patients tend to experience quicker recovery and fewer complications after spinal surgery [22]. Psychological factors, particularly depression, were also significant predictors of poor outcomes, aligning with the findings of Ferraro *et al*., and others who have shown that preoperative psychological screening can help identify patients at higher risk of poor outcomes and guide tailored treatment strategies [18]. In terms of preoperative pain intensity, the association between higher pain levels and poorer surgical outcomes is well-documented in the literature. A study by Halicka *et al*., similarly found that patients with higher baseline pain intensity were less likely to experience significant pain relief post-surgery [23]. This highlights the need for a comprehensive assessment of pain intensity and the potential role of pain management interventions prior to surgery.

Limitations of the Study

Despite the robust findings, there are several limitations to this study that should be acknowledged. First, the study was retrospective in nature, meaning that the data were collected from existing medical records, which may introduce bias and limit the ability to establish causality. Additionally, the study relied on subjective measures such as the VAS and PHQ-9 for assessing pain and psychological distress, which may be influenced by the patient's self-reporting. Future prospective studies with more objective measures, such as neuroimaging or genetic markers, could provide more insight into the underlying mechanisms of chronic pain and surgical outcomes.

Another limitation is the relatively short follow-up period of 12 months, which may not capture long-term outcomes or complications that can emerge after spinal surgery. Longer follow-up periods are needed to better understand the durability of surgical outcomes and the potential for recurrence of pain or other complications. Lastly, the study did not differentiate between specific types of spinal disorders (e.g., herniated discs vs. spinal stenosis), which may have different prognoses and surgical requirements. Future research should consider subgroup analyses based on the specific spinal condition being treated.

CONCLUSION

This study highlights the significant predictors of success in spinal surgery for chronic pain, including preoperative pain intensity, psychological distress, and comorbidities such as obesity and diabetes. Younger patients and those with lower psychological distress and lower preoperative pain levels demonstrated better surgical outcomes. The findings emphasize the need for comprehensive preoperative evaluations, including psychological assessments and pain management, to optimize surgical success. This study contributes valuable insights that can guide clinical decision-making in spinal surgery, ultimately improving patient outcomes.

Recommendations

Implement routine psychological assessments for chronic pain patients prior to spinal surgery.

Focus on preoperative pain management strategies to reduce pain intensity.

Consider personalized treatment plans based on patient comorbidities and age for better surgical outcomes.

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