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The impacts of comorbid diseases on surgical and clinical outcomes in spondylolisthesis surgery

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ABSTRACT

Aims: Management of comorbidities has a significant bearing on clinical outcomes from surgery, especially in the context of wound healing and pain management. This study aims to compare surgical patients with comorbidity (case group) and without (control group) based on recovery outcomes.

Methods: Surgical patients n=150 were enrolled patients in the case group (n=75), and control group (n=75). We collected and compared baseline demographic data, preoperative and postoperative pain levels based on the Visual Analogue Scale, discharge outcomes and assessment of wound healing. Factors affecting wound healing were evaluated using multivariate logistic regression, and predictors of postoperative pain were examined with multivariate linear regression.

Results: Demographic data revealed that the groups were comparable regarding age (p=0.122) and gender (p=0.758). The case group did have a higher mean body-mass index (BMI) of 28.9±3.4 than the control group mean BMI, which was 25.7±2.9; (p<0.001). Preoperative 7.5±1.2 vs 6.8±1.1, (p=0.001) and postoperative 4.8±1.5 vs 3.2±10, (p<0.001), pain scores were significantly greater in the case group. This is especially true for the case group, as only 40% were discharged in less than or equal to 24 hours compared with 73.3% of control (p<0.001). Cure of all wounds occurred in 90.7% of controls compared with 66.7% of cases (p<0.001), and delayed healing was significantly greater in cases (33.3% vs 9.3%, p=0.002). The case group had an odds ratio of 0.25 (p<0.001) for complete wound healing on multivariate analysis whereas group status, age, BMI and diabetes mellitus were significant postoperative pain predictors.

Conclusion: These findings highlight the need to direct resources towards preoperative evaluations before spondylolisthesis surgery and strategies in recovery after surgery for patients with diseases/disorders relevant to common problems seen.

Keywords: Spondylolisthesis, comorbid diseases, wound healing, spine surgery

INTRODUCTION

Spondylolisthesis is a spinal disorder with the anterior slipping of one vertebra relative to another, giving rise to varying degrees of instability and neurological impairment. This can occur at any level of the lumbar spine, but happens more commonly in L4-L5 and L5-S1 segments. Spondylolisthesis comes in multiple types (isthmic, degenerative, traumatic or pathological) each with a different etiology and clinical significance.[1] The prevalence of spondylolisthesis differs widely between age groups or populations.[2] Studies have shown that it is isthmic spondylolisthesis is incredibly common in young people, especially sports, this has been estimated at owners 5-7%. Some studies say degenerative spondylolisthesis more frequent in older people, approximately 20% of individuals over the age of 50 will develop this condition is less typical.[3]

Moreover, although the disorder is more prevalent in women as compared to men, especially among degenerative types (suggesting hormonal factors such as changes after menopause affecting bone density and spinal fortitude). Additionally, geographical and ethnic disparities exist as some hereditary groups with a tendency towards spinal disorders have shown higher prevalence.[4] Clinically relevant, spondylolisthesis symptom severity ranges from mild discomfort to extreme pain and disability. In rare cases, nerve root compression may result in neurological deficits; patients often present with low back pain radiating to the lower extremities and muscle spasms.[5]

If the slippage compresses the spinal cord or nerve roots, it can cause pain, numbness, or weakness of the legs.[6] Radiculopathy is when nerve roots are compressed, leading to pain or sensory changes radiating down the lower extremities which often feels like shooting pain and can be debilitating. Spondylolisthesis is related with chronic pain syndromes that

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have enormous impact in the quality of life of the patient. This disease affects the physical mobility of an individual, leading to less participation in daily activities making mental health problems worse such as depression and anxiety.[7] Management is generally medical for chronic pain syndromes, and has a significant effect on the patient's quality of life.[8] The disease can significantly limit the physical activity of people with limiting their ability to move and participate in day-to-day activities contributing to mental health issues like depression and anxiety. Obesity, for example, can impede rehabilitation efforts and is linked to an increased risk of surgical complications. Diabetes can also worsen wound healing and make a person more prone to infections. To maximize surgical outcomes for patients with spondylolisthesis, a comprehensive evaluation and management of comorbidities are essential. This ensures that interventions are customized to each patient's particular health profile to produce the greatest outcomes.[9]

There are many studies relating comorbidity to adverse surgical outcomes regardless of procedure, illustrates the universal impact of comorbidities on the surgical outcomes.[10] These studies indicate that greater challenges in managing pain, slower wound healing, prolonged recovery time, and higher complication rates are common occurrences in patients who also have comorbidity factors such as obesity, diabetes, and cardiovascular disease. In fact, researches have shown that diabetes can impair the healing of surgical wounds leading to a greater risk of surgical site infections and longer hospital stays whereas obesity may cause increased postoperative pain and analgesic requirements.[11]

Comorbidities can impact surgical outcomes via different pathways, ranging from biological mechanisms such as reduced immune response to porous tissue perfusion which may contribute to delayed recovery. Likewise, comorbidities often require more complex perioperative management, as well as surgical techniques or anesthesia choice. Although comorbidities and surgical outcomes have been well described in the literature, there is limited information on these details specific to spondylolisthesis.[12] Most of the contemporary literature on spondylolisthesis surgery fails to take into account how comorbid disorders interact to affect the individual processes underlying both long-term recovery from disability and functional improvement. A comprehensive knowledge of the drug–drug interactions that exist for each clinical situation we may encounter in this setting is, however, critical for appropriate risk stratification and management planning as it allows clinicians to identify high-risk patients who will benefit from more aggressive postoperative care or further optimization preoperatively.[13] Focusing on outcomes such as pain, wound healing rates, recovery curves over time and complications measured by frequencies, our study was analysing the impact of different comorbidities on surgical results in spondylolisthesis patients. This study is designed to provide information that could translate into clinical practice, effective management of patients in cardiothoracic surgery, and most importantly lead to improved surgical outcomes.

Our study aims to compare surgical patients with comorbidity (case group) and without (control group) based on recovery outcomes.

METHODS

The study was carried out with the permission of the Hitit University Faculty of Medicine Clinical Researches Ethics Committee (Date: 17.12.2022, Decision No: 2022-14). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

This cross-sectional study was conducted in a cohort of 150 patients who were diagnosed with spondylolisthesis requiring surgery. The study duration was six months from Feb 2023 to Jul 2023 at Çorum Erol Olçok Training and Research Hospital, Department of Neurosurgery. Patients were classified into two groups at baseline in equal number of patients. Diabetes mellitus, hypertension, and aspirin intake were history in 75 cases of patients paralleled with the case group. It compared each case subject to 75 age- and sex-matched controls without any of these disorders.

Inclusion criteria: Confirmed diagnosis of spondylolisthesis, age range 18-60 years and the willingness to follow the study's guidelines and finish all necessary tests is a must.

Exclusion criteria: As we were analyse patients with bleeding disorders, those who also had other underlying diseases (for example: haemophilia) or difficulties for blood clotting medications that affected blood clotting were excluded from our study.

Total patient number was 150 followed through the hospital registration system. Background data including age, sex, body-mass index (BMI) and surgery duration were taken from the patient's files. Our study examined the following outcomes. Measures: Visual Analogue Scale (VAS) for the severity of, (Q1) preoperative radicular pain and (Q2) postoperative radicular pain (grade 0-10: grade 0=no pain; grade 10=as severe as I could imagine). Discharge status from Surgical Site: The status of discharge was collected. Wound healing: The patient was interviewed, and the surgical field inspected through at physical examination by a neurosurgeon.

Statistical Analysis

The data was analysed by SPSS 21. Quantitative variables are presented as mean±standard deviation (SD) and categorical variables are summarized using frequency (percentage). Continuous variables were compared using a T test or Mann-Whitney test, depending on data distribution and the reaction of equal variances between study groups. Statistical analysis p values ≤0.05 were deemed statistically significant.

RESULTS

Table 1 displays the baseline characteristics of subjects who were segregated into two categories, the control group (normal patients without underlying comorbidities) and the case group (patients with comorbids).

Table 1. Baseline characteristics of patients

Characteristic	Case group (n=75)	Control group (n=75)	p-value
Age (years)	39.0±12.4	39.8±11.5	0.122
Gender (M/F)	40/35	42/33	0.758
BMI (kg/m^2)	28.9±3.4	25.7±2.9	<0.001
Duration of surgery (min)	120.3±15.2	110.1±10.8	0.004

M/F: Male/female, BMI: Body-mass index, min: Minute

The average age of the control group is 39.8 years. The average age of the case group was 39.0 years. The p-value for age is 0.122, which indicates that the two groups are equal concerning this covariate and therefore do not differ statistically from each other in terms of this variable. Likewise there is no significant difference in the gender distribution; 40 males and 35 females in case group while 42 males and 33 females in control group (p=0.758). The mean BMI of the case group is 28.9 (±3.4), which is significantly higher than that of the control group, whose mean BMI equals 25.7 (±2.9). A significant difference was found between case and control groups where the average weight for cases is heavier (p-value in BMI <0.001). Regarding the duration of the surgery the average time for the case group was 120.3 minutes (±15.2), and the control group 110.1 minutes (±10.8). The p-value, here, 0.004, shows its statistically significant difference which means the procedure in the case group takes longer. All data were entered into Statistical Package for the Social Sciences software (version 23). Differences in continuous variables such as age, BMI and length of operation of continuous variables were analyzed using the independent samples T test whereas.

Table 2 and Figure 1 reveals that both groups (case and control group) were assessed for radicular pain preoperatively and six weeks after surgery using the VAS. Preoperative VAS, the case group's score=7.5 (±1.2), demonstrates considerable pain levels before surgery. However, the control group's preoperative VAS score is much lower at 6.8 (±1.1). Statistical comparison of preoperative pain between two groups showed statistically significant differences between two groups, p value=0.001 indicating that a case group is more deluged by the pain as compared to the control group. Postoperatively, VAS is 4.8 (±1.5) for the case group and significantly lower at 3.2 (±1.0) for the control group, respectively. The postoperative pain for patients in the case group remains more severe postoperatively (p<0.001) suggesting a highly significant difference. Continuous variables: differences were analyzed using an independent samples T test.

Table 2. The severity of preoperative and postoperative radicular pain measured by the VAS

Pain measurement	Case group (n=75)	Control group (n=75)	p-value
Preoperative VAS score	7.5±1.2	6.8±1.1	0.001
Postoperative VAS score	4.8±1.5	3.2±1.0	<0.001

VAS: Visual Analogue Scale

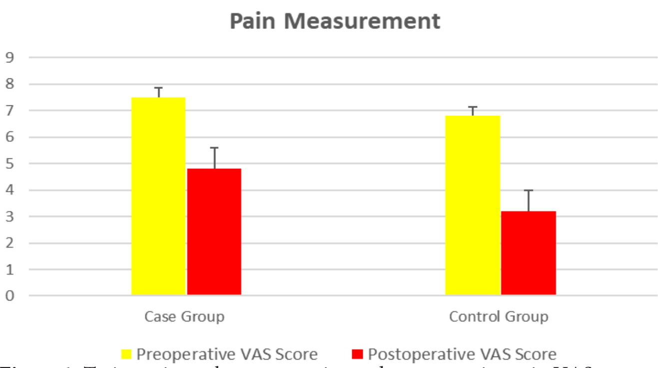

Figure 1. To investigate the preoperative and postoperative pain VAS score
VAS: Visual Analogue Scale

Table 3 and Figure 2 reveal the discharge outcomes. However, in the control group, hospital discharges occurred within 24 hours after surgery for 55 patients (73.3%) of the total. In contrast, only 30 of patients from the case group (40% of the total) were discharged from hospital. Statistically significant difference in discharge outcomes between both groups, with case group being discharged later (p<0.001). On the contrary, only 20 patients (26.7%) in control group left the ward after 24 h and 45 patients (60%) in case group with significant difference on discharge time (p=0.001). A chi-square test was performed for these categorical variables.

Table 3. Discharge from surgical site

Discharge outcome	Case group (n=75)	Control group (n=75)	p-value
Discharged within 24 hours	30 (40%)	55 (73.3%)	<0.001
Discharged after 24 hours	45 (60%)	20 (26.7%)	<0.001

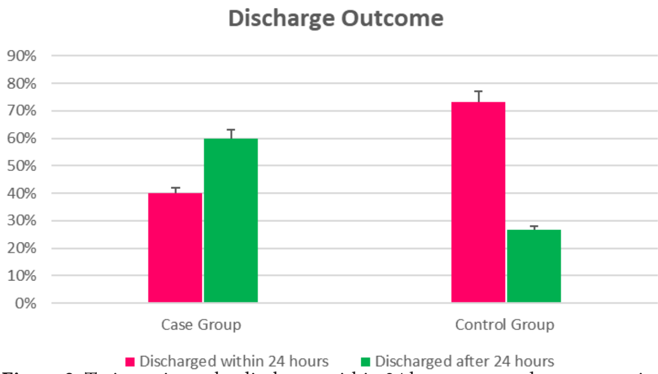

Figure 2. To investigate the discharge within 24 hours pre- and post-operative

Results of wound healing were shown in Table 4 and Figure 3. Total healing was attained in 68 patients (90.7%) of control group and 50 patients (66.7%) of case group (p<0.001). The p-value 0.002 indicates a statistically significant difference in the healing state between both experimental groups, to the favor of the control group. Moreover, delayed recovery occurred in only 25 patients (33.3%) from the case group and 7 patients (9.3%) from the control group. This difference is also statistically significant, as denoted by the identical p-value of 0.002. A chi-square test was performed to compare the wound healing status among groups.

Table 4. Wound healing assessment evaluated during follow-up visits

Wound healing status	Case group (n=75)	Control group (n=75)	p-value
Complete healing	50 (66.7%)	68 (90.7%)	0.002
Delayed healing	25 (33.3%)	7 (9.3%)	0.002

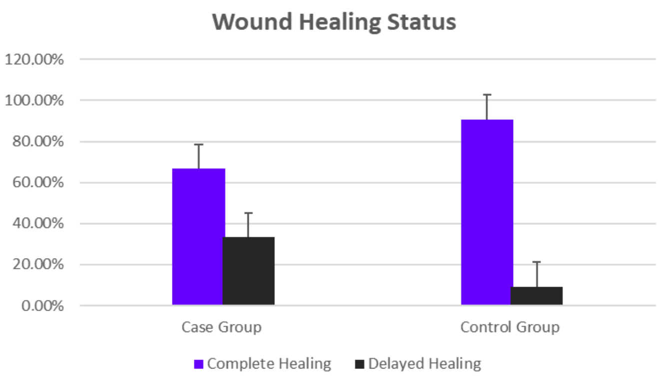

Figure 3. Wound healing was evaluated during follow-up visits

Table 5 presents the results of a multivariate logistic regression assessment of potential factors influencing postoperative wound healing status in patients.[8] Odds ratio (OR) (case vs control), 0.25; p<0.001; 95% confidence interval (CI), 0.12 to 0.53. That is to say, compared with the control group, full wound healing in patients of case group was very unlikely. Age shows an OR of 1.05 having a significant p-value (0.002) which means that with every more year of age the chances of full healing increase. There was no difference in healing status by gender with an OR of 0.80 (p=0.556), suggesting that the distinction between females and males may be negligible. Every increase in BMI is associated with a significant 12% increased odds of delayed healing [OR 1.12 (95% CI, 1.06-1.20), p=0.002]. Diabetes mellitus is associated with an OR of 0.40 (p=0.014) meaning that patients with the disease are less likely to be fully recovered. Hypertension, with an OR of 0.55 (p=0.140) showed a trend towards significantly decreased likelihood of recovery. Use of aspirin did not demonstrate a strong association with healing (OR=0.60, p=0.175). Finally, for surgery duration, the OR is 1.02 (p=0.021), indicating that increased surgical times suggest an increase in delayed wound healing risk. Overall, the study highlights key factors affecting wound healing with respect to age, BMI and diabetes status of case group.

Table 5. Multivariate logistic regression analysis of wound healing status

Variable	OR	95% CI	p-value
Group (case/control)	0.25	0.12-0.53	<0.001
Age (per year)	1.05	1.02-1.09	0.002
Gender (female/male)	0.80	0.39-1.63	0.556
BMI (per unit increase)	1.12	1.04-1.20	0.002
Diabetes mellitus	0.40	0.19-0.83	0.014
Hypertension	0.55	0.25-1.20	0.140
Aspirin use	0.60	0.29-1.24	0.175
Surgery duration (per min)	1.02	1.01-1.04	0.021

OR: Odds ratio, CI: Confidence interval, BMI: Body-mass index

Table 6 summarizes the findings from a multivariate linear regression analysis of postoperative pain in relation to various predictors. The average difference in CI value is: 1.80 (case group compared to control) with t-value of 4.00, standard error (SE): 0.45, p-value <0.001 highly significant. The implication here is that postoperative pain scores are significantly higher for case group patients than control group groups.

Table 6. Multivariate linear regression analysis of postoperative pain scores

Variable	Coefficient (β)	SE	t-value	p-value
Group (case/control)	1.80	0.45	4.00	<0.001
Age (per year)	0.05	0.02	2.50	0.013
Gender (female/male)	-0.20	0.30	-0.67	0.507
BMI (per unit increase)	0.10	0.05	2.00	0.046
Diabetes mellitus	0.90	0.40	2.25	0.027
Hypertension	0.50	0.38	1.32	0.189
Aspirin use	0.40	0.35	1.14	0.256
Surgery duration (per min)	0.02	0.01	2.00	0.047

SE: Standard error, BMI: Body-mass index

Age has a coefficient of 0.05 (p=0.013), which implies that there is an increase in postoperative pain scthes with patient age amounting to a small but statistically significant difference the p-value of the coefficient for gender is 0.507 (coefficient -0.20) indicating, respectively, that there is no difference in pain scores between males and females. The BMI coefficient of 0.10 (p=0.046) indicates that higher BMI is significantly associated with increased postoperative pain; every unit increase in the BMI scale results in a 0.1-point increase on the 10-point verbal numeric rating scale for postoperative pain, indicating moderate effect size. Diabetes mellitus is associated with coefficient (p=0.027) of 0.90, indicating that patients who are diabetic have more pain than expected after surgery. Pain scores were also influenced neither by use of aspirin nor hypertension, with respective coefficients 0.40 (p=0.256) and 0.50 (p=0.189). Finally, the length of surgery showed a coefficient of 0.02 (p=0.047) and indicating that longer surgical times are related to higher levels of postoperative pain. This analysis illustrates the effect of age, BMI, diabetes and group to predict outcomes in post-operative pain.

DISCUSSION

Spondylolisthesis a relatively common spine condition is caused by high energy traumas, degenerative changes or developmental abnormalities.[14] Surgical treatment usually involves decompression and stabilization to alleviation pain and restore function. Conversely, patient outcomes may be impacted by underlying comorbidities and surgery may additionally be complicated.[15]

The investigation of the baseline features displayed vital insights into the demographic and clinical attributes of individuals enrolled in this study. Many important characteristics were compared between the control group, which included healthy individuals without any underlying medical issues, and the case group, consisting of patients with comorbidities.[16]

No statistically significant difference was found between the two groups (p=0.122). Mean age was 39.0 years (±12.4) for case and 39.8 years (±11.5) for controls, respectively.[17] This means that the study doesn't suffer from an age-related complication and allows us to have a clearer comparison of surgery outcomes. The p-value of the gender distribution was 0.758, suggesting no apparent differences in the gender composition and limiting gender-related biases.[18]

BMI was a notable finding with a mean of 28.9 (±3.4) in the case group against a mean of 25.7 (±2.9) in controls.[19] Mean BMI was significantly lower in the control than the case group (p<0.001, and still remarkable being that this higher mean value for the case is difference in terms of percentage). Elevated BMI is commonly associated with comorbid conditions, such as diabetes, hypertension and cardiovascular disorders that can impact surgical outcomes, recovery and complications. This underscores the need for closer surveillance and tailored surgical treatment strategies in patients with elevated body mass indices.[20]

The duration of the operation was also significantly longer in the case group with a p-value of 0.004 at 120.3 minutes (±15.2) versus 110.1 minutes (±10.8) in the control group.[21] This means that the procedures performed in the case group were more complex with longer times to intervene. This extended duration might be associated with significantly protracted convalescence and an increased peril of postoperative complications, affirming that patients harboring comorbidities are best managed with targeted postoperative treatment strategies.[10]

In our study findings that preoperative postoperative pain levels had results largely similar to our studies, which adds credibility to the hypothesis of a relationship between comorbidities and pain perception. Laratta et al.,[22] conducted an exploration of pain ratings with surgical patients of different comorbidities and identified similar patterns. In their study, patients with multiple comorbidities had a mean score of 7.4 for preoperative VAS, which value is very comparable to the crusader VAS value of 7.5 in our case group. This similarity bolsters the hypothesis that baseline pain levels lit related to surgery can be dramatically raised by preoperatively malady.

In our study, it was found that the patients with comorbidities presented higher pain than healthy patients after surgery (4.6 vs. 3.1 in mean VAS score respectively). The persistence of these findings underscores the need for better pain management strategies in that population and the chronic nature of the pain faced by patients with comorbid illnesses.[23]

Additionally, Schneider et al.[24] studied the impact of other chronic diseases on early recovery outcomes and postoperative pain. The researchers found, moreover, that those with comorbidities not only reported significantly higher pain scores but also used opioids for particularly longer durations and had slower functional recovery than those without comorbidities. These findings are similar to our results, where we observed significantly higher pain scores (4.8±1.5) in the case group a week postoperatively, the rationale being that patients with higher levels of postoperative pain may become quite dependent on analgesics thereby prolonging hospital stay.[25] When taken together with earlier studies, our results show the importance of adjusting pain management protocols for surgical patients with comorbidities. Based on prior research, the unique challenges presented by these patients warrant an individualized plan for pain management aimed at optimizing recovery while minimizing complications associated with inadequate treatment of pain. Taken together, our study adds further evidence for the relationship between comorbidities and pain while also providing a rationale for precautionary measures to ensure optimal pain management in surgical cohorts at risk. Closer monitoring and longer-term care are required due to these problems, including infections, delayed mobilization, and generally poor physiological responses.[26]

Additionally, our evaluation of wound healing showed that only 66.7% of the case group experienced full healing, compared to 90.7% of the control group (p<0.001). The case group's noticeably greater rate of delayed healing (33.3% vs. 9.3%, p=0.002) supports earlier research showing how comorbidities, especially diabetes and obesity, negatively impact wound healing. For instance, compared to patients without diabetes, diabetic patients had a 40% increased risk of developing wound-healing issues, according to Farmer et al.[27] study. This is probably caused by elements linked to various disorders, such as decreased blood flow, neuropathy, and weakened immune response.

The multivariate analyses of wound healing and postoperative discomfort yield a comprehensive understanding of the key factors influencing recovery outcomes in our study. The multivariate logistic regression analysis indicated that the odds ratio of complete wound healing in the case group was substantially lower than that in the control group (0.25, p<0.001). As shown in this figure, comorbidities significantly impacted recovery, consistent with the literature indicating that several variables including age, BMI and diabetes are strong predictors of clinical wound healing outcomes.[28]

This research backs up earlier studies particularly when it came to the role of diabetes. In a landmark work by Rabah et al.[29] if patients are suffering from diabetes the chances of patient's wound healing poorly were significant during this period mainly due to decreased perfusion and immunity. As in our results, wherein case group patients had more diabetes and increased BMIs with impaired wound healing, their findings showed that diabetic patients had three times higher incidence of poor wound healing compared to non-diabetic patients. Many studies have repeatedly identified age as a predictor for impaired wound healing. They explained that older adults healed slower than younger persons due to physiological changes with aging and reduced collagen synthesis. Our inclusion of age as a strong predictor, which suggests that patients may be vulnerable to factors preventing proper healing in greater numbers the older they get, supports these results.[30]

The multivariate linear regression analysis of postoperative pain sheds further light on the factors affecting our cohort's perception of pain. These included diabetes mellitus (p=0.027), age (p=0.013), BMI (p=0.046) and group status (case v control, p<0.001). Consistent with other investigations that identified comorbid diseases as significant factors for postoperative pain, the case group had higher scores for discomfort. For example, Ge et al.[31] found that patients with higher BMIs often reported increased pain levels post-surgery due to increased tissue trauma and inflammatory responses.

In addition, diabetes has been shown to lead to high levels of pain after surgery. The people with diabetes not only feel the pain more strongly but they also likely to have a very different pathway which is altered in such as way that their suffering state may be worse as they have added pathways for pain which are further intensified due to changes occurring inside and outside of them as well. These findings are in alignment with our results demonstrating that high VAS scores were significantly associated with diabetes among the case group, suggesting that tailored pain management strategies may be especially important for this population.[32]

By demonstrating clear associations between these variables and patient recovery, our study underscores the importance of comprehensive preoperative assessments and individualized postoperative care plans. This may help enhance surgical outcomes and recovery rates, possibly in patients with comorbidity burdened health disparities. By building on earlier studies, we can better address the challenges posed by comorbidities in surgical populations. These lessons will assist us in improving our patient care and management processes.

CONCLUSION

Patients with comorbidities have blunted surgical outcomes, characterised by a higher intensity postoperative pain and slower ticks of the wound. Our findings underscore the need for risk stratification of patients undergoing surgical procedures in advance to implement targeted pre-operative assessments and postoperative rehabilitation strategies after surgery in at-risk populations. More studies are still needed to determine how to safely provide pain management and wound care safely in patients across all combinations of these health characteristics.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Hitit University Faculty of Medicine Clinical Researches Ethics Committee (Date: 17.12.2022, Decision No: 2022-14).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Fahmy MM, Hassan MES, Ismaeil AS, Kelany A, Wanis AE. Overview of clinical assessment principles of treatment of lumbar spondylolithesis. *Tob Regul Sci.* 2023;9(1):2914-2928. doi:10.18001/TRS.9.1.200
2. García-Ramos C, Valenzuela-González J, Baeza-Álvarez VB, Rosales-Olivarez LM, Alpizar-Aguirre A, Reyes-Sánchez A. Degenerative spondylolisthesis I: general principles. *Acta Ortop Mex.* 2020;34(5):324-328. doi:10.35366/97997
3. Daher M, Rezk A, Baroudi M, et al. Lumbar spondylolisthesis grading: current standards and important factors to consider for management. *World Neurosurg.* 2024;190:311-317. doi:10.1016/j.wneu.2024.07.194
4. Vanti C, Ferrari S, Guccione AA, Pillastrini P. Lumbar spondylolisthesis: STATE of the art on assessment and conservative treatment. *Arch Physiother.* 2021;11(1):19. doi:10.1186/s40945-021-00113-2
5. Hsu HC, Chang CJ, Tung HH, Wang TJ. Disability, emotional distress and well-being among patients with lumbar spondylolisthesis. *J Clin Nurs.* 2019;28(21-22):3866-3878. doi:10.1111/jocn.14992
6. Mirzamohammadi E, Ghandhari H, Pirbornatan M, Mohammadi S, Hosseininejad M. Assessment of disability levels in patients with low back pain based on the type of lumbar spinal disorder. *J Back Musculoskelet Rehabil.* 2021;34(1):131-137. doi:10.3233/BMR-191679
7. Austevoll IM, Hermansen E, Fagerland MW, et al. Decompression with or without usion in degenerative lumbar spondylolisthesis. *N Engl J Med.* 2021;385(6):526-538. doi:10.1056/NEJMoa2100990
8. Mohile NV, Kuczmarski AS, Lee D, Warburton C, Rakoczy K, Butler AJ. Spondylolysis and isthmic spondylolisthesis: a guide to diagnosis and management. *J Am Board Fam Med.* 2022;35(6):1204-1216. doi:10.3122/jabfm.2022.220130R1
9. Traistaru MR, Kamal D, Kamal C, Alexandru DO, Neamtu S-D, Bumbea AM. Quality of life in osteoporotic patients with low-grade degenerative spondylolisthesis. *Signa Vitae.* 2022;18(6):66-75. doi:10.22514/sv.2022.022
10. Buyuk AF, Shafa E, Dawson JM, Schwender JD. Complications with minimally invasive transforaminal lumbar interbody fusion for degenerative spondylolisthesis in the obese population. *Spine (Phila Pa 1976).* 2019;44(23):E1401-E1408. doi:10.1097/BRS.0000000000003160
11. Bays A, Stieger A, Held U, et al. The influence of comorbidities on the treatment outcome in symptomatic lumbar spinal stenosis: a systematic review and meta-analysis. *N Am Spine Soc J.* 2021;6:100072. doi:10.1016/j.xnsj.2021.100072
12. Urakawa H, Jones T, Samuel A, et al. The necessity and risk factors of subsequent fusion after decompression alone for lumbar spinal stenosis with lumbar spondylolisthesis: 5 years follow-up in two different large populations. *Spine J.* 2020;20(10):1566-1572. doi:10.1016/j.spinee.2020.04.026
13. Mazurek M, Kulesza B, Gołębiowska N, Tyzo B, Kura K, Szczepanek D. Factors predisposing to the formation of degenerative spondylolisthesis-a narrative review. *Medicina (Kaunas).* 2023;59(8):1430. doi:10.3390/medicina59081430
14. Rivollier M, Marlier B, Kleiber J-C, Eap C, Litre C-F. Surgical treatment of high-grade spondylolisthesis: technique and results. *J Orthop.* 2020;22:383-389. doi:10.1016/j.jor.2020.08.015
15. Chakravarthy V, Patel A, Kemp W, Steinmetz M. Surgical treatment of lumbar spondylolisthesis in the elderly. *Neurosurg Clin N Am.* 2019;30(3):341-352. doi:10.1016/j.nec.2019.02.008
16. Wollowick AL, Sarwahi V. Spondylolisthesis: Diagnosis, Non-Surgical Management, and Surgical Techniques: Springer Nature; 2023.
17. Karsy M, Chan AK, Mummaneni PV, et al. Outcomes and complications with age in spondylolisthesis: an evaluation of the elderly from the quality outcomes database. *Spine (Phila Pa 1976).* 2020;45(14):1000-1008. doi:10.1097/BRS.0000000000003441
18. Inose H, Kato T, Onuma H, et al. Predictive factors affecting surgical outcomes in patients with degenerative lumbar spondylolisthesis. *Spine (Phila Pa 1976).* 2021;46(9):610-616. doi:10.1097/BRS.0000000000003944
19. Agarwal N, Aabedi AA, Chan AK, et al. Leveraging machine learning to ascertain the implications of preoperative body mass index on surgical outcomes for 282 patients with preoperative obesity and lumbar spondylolisthesis in the quality outcomes database. *J Neurosurg Spine.* 2022;38(2):182-191. doi:10.3171/2022.8.SPINE22365
20. Lubis DU, Harahap EE, Iqbal KM. Correlation of body-mass index, age and gender with the degree of spondylolisthesis on lumbosacral xray photos at Haji Adam Malik Hospital Medan. *Med Res Nurs Health Midwife Participat.* 2024;5(3):133-144. doi:10.59733/medalion.v5i3.124
21. Adogwa O, Davison MA, Vuong V, et al. Sex Differences in opioid use in patients with symptomatic lumbar stenosis or spondylolisthesis undergoing lumbar decompression and fusion. *Spine (Phila Pa 1976).* 2019;44(13):E800-E807. doi:10.1097/BRS.0000000000002965
22. Laratta J, Carreon LY, Buchholz AL, et al. Effects of preoperative obesity and psychiatric comorbidities on minimum clinically important differences for lumbar fusion in grade 1 degenerative spondylolisthesis: analysis from the prospective quality outcomes database registry. *J Neurosurg Spine.* 2020;33(5):635-642. doi:10.3171/2020.4.SPINE20296
23. Bond M, Evaniew N, Bailey CS, et al. Back pain in surgically treated degenerative lumbar spondylolisthesis: what can we tell our patients? *Spine J.* 2020;20(12):1940-1947. doi:10.1016/j.spinee.2020.08.009
24. Schneider N, Fisher C, Glennie A, et al. Lumbar degenerative spondylolisthesis: factors associated with the decision to fuse. *Spine J.* 2021;21(5):821-828. doi:10.1016/j.spinee.2020.11.010
25. Inculet C, Urquhart JC, Rasoulinejad P, et al. Factors associated with using an interbody fusion device for low-grade lumbar degenerative versus isthmic spondylolisthesis: a retrospective cohort study. *J Neurosurg Spine.* 2021;35(3):299-307. doi:10.3171/2020.11.SPINE201261
26. Goh GS, Yue WM, Guo CM, Tan SB, Chen JLT. Does the predominant pain location influence functional outcomes, satisfaction, and return to work after minimally invasive transforaminal lumbar interbody fusion for degenerative spondylolisthesis? *Clin Spine Surg.* 2022;35(1):E143-E149. doi:10.1097/BSD.0000000000001193

27. Farmer S, Choi D. Spinal Column and Spinal Cord Disorders. Neurology: A Queen Square Textbook. 2016.

28. Mummaneni PV, Bydon M, Knightly J, et al. Predictors of nonroutine discharge among patients undergoing surgery for grade I spondylolisthesis: insights from the quality outcomes database. *J Neurosurg Spine*. 2019;32(4):523-532. doi:10.3171/2019.9.SPINE19644

29. Rabah NM, Khan HA, Shost M, Beckett J, Mroz TE, Steinmetz MP. Predictors of operative duration and complications in single-level posterior interbody fusions for degenerative spondylolisthesis. *World Neurosurg*. 2021;151:e317-e323. doi:10.1016/j.wneu.2021.04.034

30. Fatima N, Zheng H, Massaad E, Hadzipasic M, Shankar GM, Shin JH. Development and validation of machine learning algorithms for predicting adverse events after surgery for lumbar degenerative spondylolisthesis. *World Neurosurg*. 2020;140:627-641. doi:10.1016/j.wneu.2020.04.135

31. Ge Z, Liu X, Jing X, et al. Logistic regression model predicts early surgical site infection after spinal fusion: a retrospective cohort study. *J Hosp Infect*. 2024;149:65-76. doi:10.1016/j.jhin.2024.04.018

32. Khan JM, Harada GK, Basques BA, et al. Patients with predominantly back pain at the time of lumbar fusion for low-grade spondylolisthesis experience similar clinical improvement to patients with predominantly leg pain: mid-term results. *Spine J*. 2020;20(2):276-282. doi:10.1016/j.spinee.2019.09.021