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Clinical Study of Applying Enhanced Recovery after Surgery Concept in Single-Segment Lumbar Spinal Stenosis Surgery

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Abstract

Objective: With the aging population and changes in lifestyle, lumbar spinal stenosis has become a common spinal disorder. Treatment modalities have been advancing, and the application of Enhanced Recovery After Surgery (ERAS) principles provides a new approach to postoperative recovery in patients. This study aims to investigate the clinical application effects of ERAS principles in single-level lumbar spinal stenosis surgery. **Methods:** This study included 64 patients who underwent lumbar fusion surgery in the Spinal Surgery Department of Baise People's Hospital from July 2022 to July 2024. These patients were divided into an experimental group (ERAS group, 33 cases) and a control group (conventional group, 31 cases) based on perioperative care, receiving ERAS principles and traditional treatment, respectively. A comparison was made between the two groups in terms of gender, age, BMI, intraoperative blood loss, postoperative length of hospital stay, postoperative complications, hospital costs, VAS scores (preoperative/postoperative day 3), and ODI scores (preoperative/postoperative day 3). **Results:** There were no significant differences in gender, age, and BMI between the ERAS group and the conventional group (gender: $\chi^2 = 0.5008$, P = 0.4792; age: 54.55 ± 8.51 years vs. 57.39 ± 8.16 years, P = 0.0892; BMI: 25.11 ± 2.70 vs. 24.77 ± 2.75, P = 0.3098). However, during surgery, patients in the ERAS group had significantly less blood loss than those in the conventional group (197.58 ± 195.51ml vs. 438.71 ± 349.22 ml, P = 0.0006), and the postoperative length of hospital stay was significantly shorter (7.00 ± 2.24 days vs. 11.55 ± 5.23 days,

P = 0.0000). On postoperative day 3, VAS scores were significantly better in the ERAS group compared to the conventional group (3.70 ± 0.88 vs. 4.32 ± 0.87, P = 0.0031), and the ODI scores showed significant improvement as well (46.00 ± 3.04 vs. 48.00 ± 3.39, P = 0.0078). Although there were no significant differences in postoperative complications and hospital costs (complications: 3 cases vs. 0 cases, P = 0.2154; hospital costs: 63524.29 ± 17891.80 RMB vs. 58733.84 ± 13280.82 RMB, P = 0.1154), ERAS demonstrated better postoperative recovery outcomes in single-level lumbar spinal stenosis surgery. **Conclusion:** The study results support the implementation of ERAS principles in single-level lumbar spinal stenosis surgery to promote rapid recovery, reduce healthcare resource consumption, and improve overall patient satisfaction.

Keywords

Enhanced Recovery after Surgery Concept, Single-Segment, Lumbar Spinal Stenosis, Perioperative Period, VAS Score, ODI Score

1. Background

Enhanced Recovery After Surgery (ERAS), also known as rapid recovery or early rehabilitation, is a multimodal perioperative management strategy aimed at reducing the physiological and psychological stress of surgical patients, shortening hospital stays, accelerating postoperative recovery, and lowering the risk of complications through scientifically validated interventions [1] [2]. This concept originated in Denmark in the 1990s, initially applied to colorectal surgeries and later expanded to other surgical fields, including cardiac, orthopedic, and gynecological surgeries [3]. The ERAS philosophy emphasizes teamwork [4], involving collaboration among various professionals such as surgeons, anesthesiologists, nurses, nutritionists, and physical therapists to provide comprehensive care for patients. The application of the ERAS concept in spinal surgery [5] [6], particularly for common conditions like lumbar spinal stenosis, can significantly improve patients' postoperative experiences and recovery speed. Through carefully designed preoperative, intraoperative, and postoperative management, patients can return to normal life more quickly, enhancing their quality of life [7]. Therefore, this study aims to evaluate the effectiveness, accuracy, and safety of applying the ERAS concept in single-segment lumbar spinal stenosis surgery, including aspects such as patient gender, age, BMI, intraoperative blood loss, postoperative hospital stay, complications, hospital costs, VAS scores (preoperative/postoperative day 3), and ODI scores (preoperative/postoperative day 3). The following is the report of the study results.

2. Materials and Methods

2.1. Study Subjects

This study adopted a prospective randomized controlled trial design to investi-

gate the effects of applying the Enhanced Recovery After Surgery (ERAS) concept in patients undergoing single-segment lumbar spinal stenosis surgery at the Southwest Hospital affiliated to Youjiang Medical University for Nationalities in Baise City from July 2022 to July 2024. A total of 64 patients were included in the study, including 22 males and 42 females. All patients underwent surgery targeting specific lumbar vertebral segments, with the distribution as follows: surgery on the L2/3 segment in 2 cases, L3/4 segment in 5 cases, L4/5 segment in 40 cases, and L5/S1 segment in 17 cases. Prior to study inclusion, all participants were fully informed about the research and had signed informed consent forms. Additionally, this study protocol has been approved by the Ethics Committee of Baise City People's Hospital (Southwest Hospital affiliated to Youjiang Medical University for Nationalities). All surgeries were performed by the same experienced team of attending physicians under the supervision and guidance of the Chief of Spine Surgery.

2.2. Study Methods

Methods for the ERAS group and conventional group (see Table 1), the surgical scene is shown in Figure 1(A) and Figure 1(B).

Table 1. Comparison of Research Methods in Two Groups.

Perioperative	Item	ERAS Group	Standard Group
Preoperative	Preoperative Education	Detailed explanation to patients about ERAS-related hospitalization precautions, measures, and procedures.	Detailed explanation to patients about non-ERAS-related hospitalization precautions, measures, and procedures.
	Preoperative Nutrition	Preoperative assessment of patient's nutritional status by a nutritionist and providing corresponding adjustment advice.	Maintaining the patient's normal dietary habits preoperatively.
	Fasting	Stop solid food intake 6 hours before surgery, allow oral intake of 200 ml carbohydrate-containing liquid 2 hours before general anesthesia induction.	No solid food intake 8 hours before surgery, no water intake 6 hours before surgery.
	Preemptive Analgesia	Provide intravenous ibuprofen injection to achieve preemptive analgesia 1 day before surgery.	None.
Intraoperative	Controlled Hypotension	Maintain systolic blood pressure at 80 - 90 mmHg and diastolic blood pressure at 50 - 65 mmHg during surgery.	Maintain systolic blood pressure at 90 - 120 mmHg and diastolic blood pressure at 60 - 90 mmHg during surgery.
	Surgical Approach	Tianji orthopedic robot-assisted minimally invasive surgery.	Conventional open surgery under C-arm guidance.
	Local Anesthesia	Subcutaneous injection of 1% ropivacaine and ibuprofen during wound closure.	None.
Postoperative	Pain Management	Intravenous ibuprofen injection for the first 3 days postoperatively, followed by oral etoricoxib from 3 days to 1 week postoperatively.	Intravenous ibuprofen injection for the first 3 days postoperatively, followed by oral etoricoxib from 3 days to 2 weeks postoperatively.

Continued

Postoperative	Feeding	Allow small amount of water if the patient is conscious postoperatively.	Allow small amount of water if the patient is conscious postoperatively.
	Early Mobilization	Immediately start passive leg exercises postoperatively and wear a lumbar support belt from day 2 to day 3 postoperatively. Patients will be guided to sit up in bed and attempt walking once they feel no dizziness. A personalized activity plan will be developed by rehabilitation doctors. The drainage tube will be removed 1 - 2 days after stable drainage, and discharge will be arranged after observing good wound healing for one day.	Immediately start passive leg exercises postoperatively and wear a lumbar support belt from day 3 to day 4 postoperatively. Patients will be guided to sit up in bed and attempt standing and walking once they feel no dizziness. A personalized activity plan will be developed by rehabilitation doctors. The drainage tube will be removed after stable drainage, and discharge will be arranged after 2 - 3 days of observation with good wound healing.

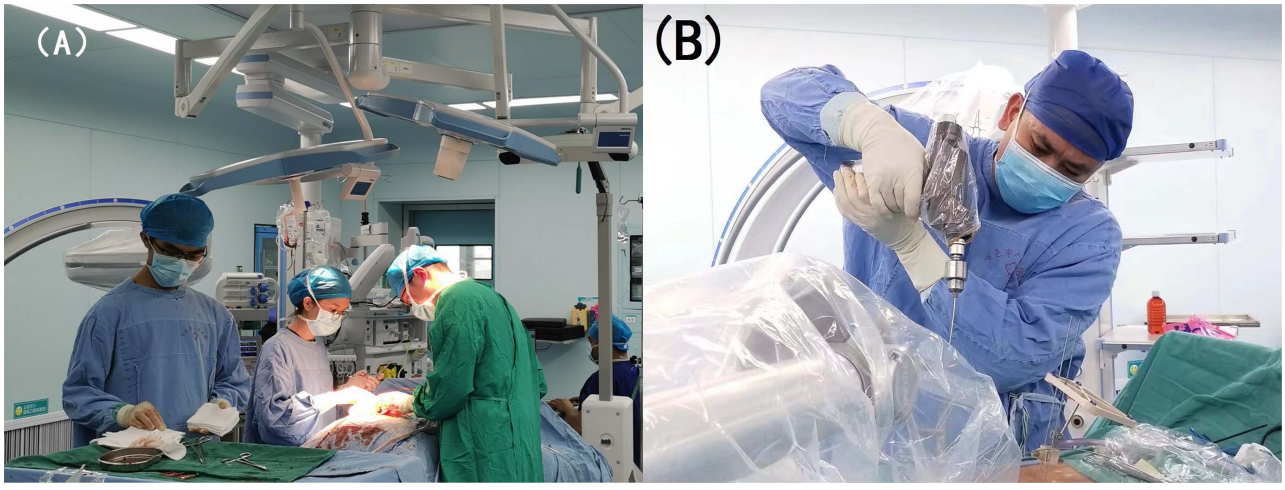

Figure 1. (A) shows the surgical scene of the control group; (B) shows the surgical scene of the robotic group.

2.3. Inclusion

Criteria Patients included in this study must meet the following criteria: 1) Diagnosed with lumbar spinal stenosis; 2) Individuals who underwent single-level lumbar spinal stenosis surgery under the guidance of Enhanced Recovery After Surgery (ERAS) principles; 3) Patients who underwent single-level lumbar spinal stenosis surgery without following ERAS principles; 4) All patients should not have underlying conditions that could independently impact postoperative outcomes, such as severe coronary artery disease or cerebrovascular disease.

2.4. Exclusion

Criteria Exclusion criteria include: 1) Presence of severe systemic diseases; 2) History of at least one previous spinal surgery; 3) History of severe osteoporosis, malignant tumors, tuberculosis, or infections related to bone diseases; 4) Cases requiring transfer to other departments or hospitals for further treatment due to the occurrence of major postoperative complications.

2.5. Statistical Analysis

Statistical analysis in this study was conducted using SPSS 27.0 software. For quantitative data, results are presented in the form of mean ± standard deviation ($\bar{x}$ ± s) and compared using t-tests; categorical data is presented as percentages (%) and analyzed using chi-square (χ^2) tests. Statistical significance was considered only when the p-value was less than 0.05.

3. Results

3.1. Comparison of Patients' General Data

A total of 64 cases were included in this study, from July 2022 to July 2024, at the Southwest Hospital affiliated with Baise City People's Hospital (Yuejiang Ethnic Medicine College), who underwent single-level lumbar spinal stenosis surgery with and without the application of Enhanced Recovery After Surgery (ERAS) principles. Among them, there were 10 male and 23 female patients in the ERAS group, and 12 male and 19 female patients in the conventional group. The comparison of gender between the two groups showed no statistically significant difference (χ^2 = 0.5008). The average age in the ERAS group was 54.55 ± 8.51 years, and in the conventional group was 57.39 ± 8.16 years. The average BMI in the ERAS group was 25.11 ± 2.70 kg/m^2, and in the conventional group was 57.39 ± 8.16 kg/m^2. There were no statistically significant differences in gender, age, BMI, and other preoperative general data between the two groups (P > 0.05). Please refer to Tables 2-4 for detailed information.

Table 2. Comparison of gender between the two groups of patients.

Group	Number	Male	Female	χ^2 Value	P Value
Conventional Group	31	12	19	3.1613	0.0754
ERAS Group	33	10	23	10.2424	0.0014
χ^2 Value	—	0.5008	—	—	—
P Value	—	0.4792	—	—	—

The results in **Table 2** show a significant difference in gender between the ERAS group and the conventional group, with the ERAS group having a lower proportion of males and a higher proportion of females, while the conventional group has a relatively balanced gender distribution. The χ^2 value is 10.2424 with a P value of 0.0014, indicating a significant difference in gender between the two groups.

Table 3. Comparison of general data between the two groups of patients.

Group (12 males, 19 females)	Number	Average Age	Male	Female	t Value	P Value
Conventional Group	31	57.39 ± 8.16	57.10 ± 11.94	53.43 ± 6.54	0.9763	0.1685
ERAS Group (10 males, 23 females)	33	54.55 ± 8.51	55.75 ± 10.08	58.42 ± 6.78	0.8943	0.1944
t Value	—	1.3610	0.2830	2.4121	—	—
P Value	—	0.0892	0.3900	0.0103	—	—

The results in Table 3 show the comparison of general data between the two groups of patients. There were no statistically significant differences in average age, gender distribution, and other general data between the Conventional Group and the ERAS Group ($P > 0.05$).

3.2. Comparison of BMI, Intraoperative Blood Loss, Postoperative Hospital Stay, Postoperative Complications, and Total Hospital Costs between the Two Groups

The comparison of BMI between the two groups showed no significant difference, with a P value greater than 0.05. The ERAS group had significantly less intraoperative blood loss compared to the Conventional group, with the ERAS group having an intraoperative blood loss of (197.58 ± 195.51) ml, while the Conventional group had (438.71 ± 349.22) ml, showing a significant difference between the two groups with a P value less than 0.05. The postoperative hospital stay was shorter in the ERAS group compared to the Conventional group, with the ERAS group having a postoperative hospital stay of (7.00 ± 2.24) days, while the Conventional group had (11.55 ± 5.23) days, indicating a significant difference in hospital stay between the two groups with a P value less than 0.05. The occurrence rate of postoperative complications was lower in the ERAS group compared to the Conventional group, with the ERAS group having 0 cases of postoperative complications and a 0% occurrence rate, while the Conventional group had 3 cases with a 9.6774% occurrence rate. However, based on statistical analysis, it cannot be concluded that the occurrence rate of postoperative complications in the ERAS group is lower than in the Conventional group, as the difference between the two groups was not statistically significant with a P value greater than 0.05. The average total hospital costs in the ERAS group were higher than in the Conventional group, with the ERAS group's total hospital costs being (63524.29 ± 17891.80) yuan, while the Conventional group's total hospital costs were (58733.84 ± 13280.82) yuan. According to statistical analysis, it cannot be determined that the total hospital costs in the ERAS group are higher than in the Conventional group, as the difference between the two groups was not statistically significant with a P value greater than 0.05. See Table 4 for details.

Table 4. Comparison of BMI, intraoperative blood loss, postoperative hospital stay, postoperative complications, and total hospital costs between the two groups of patients.

Group	Number	BMI (kg/m²)	Intraoperative Blood Loss	Postoperative Hospital Stay	Postoperative Complications	Total Hospital Costs
Conventional Group	31	24.77 ± 2.75	438.71 ± 349.22	11.55 ± 5.23	3	58733.84 ± 13280.82
ERAS Group	33	25.11 ± 2.70	197.58 ± 195.51	7.00 ± 2.24	0	63524.29 ± 17891.80
χ^2 Value or t Value	—	0.4990	3.3790	4.4737	1.5346	1.2099
P Value	—	0.3098	0.0006	0.0000	0.2154	0.1154

The results in Table 4 show a comparison of BMI, intraoperative blood loss, postoperative hospital stay, postoperative complications, and total hospital costs between the Conventional Group and the ERAS Group. There were statistically significant differences in intraoperative blood loss, postoperative hospital stay, and postoperative complications between the two groups ($P < 0.05$), while there were no significant differences in BMI, total hospital costs ($P > 0.05$).

3.3. Comparison of Pre- and Post-Operative VAS Scores in Patients

The pre-operative VAS score in the ERAS group was 7.39 ± 0.61, while in the Conventional group it was 7.48 ± 0.77. There was no statistically significant difference between the two groups, with a P value greater than 0.05. However, the VAS score on the third-day post-operation in the ERAS group was 3.70 ± 0.88, which was significantly lower than in the Conventional group (4.32 ± 0.87), showing a statistically significant difference with a P value less than 0.05. Please refer to Table 5 for detailed data.

Table 5. Comparison of pre- and post-operative VAS scores in the two groups.

Group	Number of Cases	Pre-op VAS Score	Post-op VAS Score	t-value	P-value
Conventional Group	31	7.48 ± 0.77	4.32 ± 0.87	15.1437	0.0000
ERAS Group	33	7.39 ± 0.61	3.70 ± 0.88	19.7969	0.0000
t-value	—	0.5199	2.8323	—	—
P-value	—	0.3025	0.0031	—	—

The results from Table 5 indicate that there was no significant difference in pre-operative VAS scores between the Conventional group and the ERAS group ($P = 0.3025$). However, on the third-day post-operation, the VAS score in the ERAS group was significantly lower than in the Conventional group, showing a statistically significant difference ($P = 0.0031$). This suggests that the ERAS group demonstrated better pain control post-operatively compared to the Conventional group.

3.4. Comparison of Pre- and Post-Operative ODI Scores in Patients

The pre-operative ODI scores in the ERAS group (80.24 ± 2.44) were not significantly different from those in the Conventional group (80.45 ± 2.72) ($P > 0.05$). However, on the third-day post-operation, the ODI scores in the ERAS group (46.00 ± 3.04) were significantly lower than those in the Conventional group (48.00 ± 3.39), with a statistically significant difference ($P < 0.05$). Refer to Table 6 for detailed data.

The results in Table 6 demonstrate a significant improvement in ODI scores from pre-operative to post-operative in both the Conventional group (80.45 ± 2.72 to 48.00 ± 3.39, $t = 42.3623$, $p = 0.0000$) and the ERAS group (80.24 ± 2.44

to 46.00 ± 3.04, t = 50.4589, p = 0.0000). The comparison of post-operative ODI scores between the two groups showed a statistically significant difference, with the ERAS group (46.00 ± 3.04) having a significantly lower score compared to the Conventional group (48.00 ± 3.39) (t = 2.4878, p = 0.0078).

Table 6. Comparison of pre- and post-operative ODI scores between the two groups.

Group	Number of Cases	ODI Score (Pre-Op)	ODI Score (Post-Op)	t-value	P-value
Conventional	31	80.45 ± 2.72	48.00 ± 3.39	42.3623	0.0000
ERAS	33	80.24 ± 2.44	46.00 ± 3.04	50.4589	0.0000
t-value	—	0.3255	2.4878	—	—
P-value	—	0.3729	0.0078	—	—

4. Discussion

This study aimed to explore the application of Enhanced Recovery After Surgery (ERAS) principles in single-level lumbar spinal stenosis surgery and its impact on postoperative recovery in patients. The results indicated that there were no significant differences in gender, age, and BMI between the ERAS group and the conventional group. However, the ERAS group demonstrated advantages in intraoperative blood loss, postoperative length of hospital stay, and postoperative pain scores. These findings are consistent with some domestic scholars' research results [8]-[10], further confirming the benefits and safety of ERAS principles in this surgery, which can aid in promoting patients' postoperative recovery. The significantly lower intraoperative blood loss in the ERAS group compared to the conventional group may be attributed to the minimally invasive techniques and precise operations advocated by ERAS, as supported by Xu Junhua *et al.* [11]. The significant reduction in postoperative length of hospital stay indicates that ERAS effectively promotes early patient recovery, aligning with other research findings [12], highlighting how ERAS accelerates the recovery process by optimizing perioperative management.

Although there was no significant difference in the postoperative complication rates between the ERAS group and the conventional group, three cases of complications occurred in the ERAS group compared to none in the conventional group, suggesting that ERAS may to some extent reduce the risk of complications. Due to the small sample size, this finding needs verification in larger-scale studies, as discussed by Zhao Tong *et al.* [13]. While the increase in hospitalization costs in the ERAS group was slightly higher but not significantly different, this may be due to the adoption of advanced technologies and personalized treatment plans by ERAS, leading to short-term cost increases. However, considering the potential advantages of shortened hospital stays and reduced complications with ERAS, it may bring long-term cost benefits. It is recommended to include high-tech medical equipment such as the Tianji robot in the medical insurance system to reduce the financial burden on patients and overall

lower healthcare costs.

In terms of pain management, the ERAS group had lower VAS scores on the third day postoperatively compared to the conventional group, indicating that ERAS multimodal analgesia effectively alleviates postoperative pain. The ERAS group also showed better ODI scores on the third day postoperatively compared to the conventional group, reflecting the effective improvement in postoperative functional recovery with ERAS. Consistent with previous studies [14] [15], ERAS enhances quality of life, likely associated with faster functional recovery.

In conclusion, this study suggests that ERAS has potential advantages in single-level lumbar spinal stenosis surgery, particularly in reducing intraoperative blood loss, shortening hospital stays, and improving postoperative pain management. However, for a comprehensive assessment of the actual impact of ERAS, more research is needed to explore its long-term effects on patient prognosis and achieve optimal cost-effectiveness in different healthcare settings.

5. Conclusion

The results of this study indicate that the Enhanced Recovery After Surgery (ERAS) concept has potential clinical value in single-segment lumbar spinal stenosis surgery. By reducing intraoperative blood loss, shortening hospital stay, and improving postoperative pain and functional disability scores, ERAS provides patients with better conditions for recovery. However, further research is needed to comprehensively evaluate the actual impact of ERAS, including its long-term effects and cost-effectiveness.

6. Limitations and Future Directions of Research

This study has some limitations, primarily due to a relatively small sample size, which limits our statistical power for certain variables, especially in analyzing complications and hospital costs. Future studies should expand the sample size to more accurately assess the effectiveness of ERAS strategies and consider factors such as age, gender, and comorbidities on outcomes. Additionally, although this study did not observe significant advantages in terms of postoperative complications and hospital costs in the ERAS group, this does not rule out the possibility of potential benefits of ERAS in long-term follow-up. Therefore, future research should include long-term follow-up to evaluate the impact of ERAS on patients' long-term prognosis.

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Conflicts of Interest

For the publication of this paper, all members of the research group hereby declare that there are no conflicts of interest among the authors in the order of authorship.

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