Evaluation of the Use of Monopolar Low-Temperature Plasma Electrode in Lumbar Spinal Canal Expansion, Decompression, Bone Grafting, and Fusion Internal Fixation Surgery

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Abstract: Objective: This study aims to explore the therapeutic effects of using a monopolar low-temperature plasma electrode and a high-frequency electrotome during lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery. The study also investigates the impact of these techniques on inflammatory indicators and quality of life in patients. Methods: A total of 100 patients with lumbar spondylolisthesis treated between June (January) 2022 and July (March) 2023 were selected for this study. They were randomly divided into a control group and an observation group, with 50 cases in each group. Both groups underwent lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery. The control group used a high-frequency electrotome during surgery, while the observation group used a monopolar low-temperature plasma electrode. Surgical indicators (operation time, intraoperative blood loss), inflammatory indicators, pain levels, and quality of life were compared between the two groups. Results: The operation time in the observation group was shorter than that in the control group ($P<0.05$). Postoperative levels of TNF-α and CRP were lower in the observation group than in the control group ($P<0.05$). The observation group had lower VAS scores and higher SF-36 scores compared to the control group ($P<0.05$). Conclusion: The use of a monopolar low-temperature plasma electrode in lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery yields positive therapeutic outcomes. It effectively reduces operation time, alleviates patient's inflammatory responses and pain levels, aids in postoperative recovery, and enhances quality of life. These results suggest the potential for wider adoption.

***Keywords*:** lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery, monopolar low-temperature plasma electrode, high-frequency electrotome, lumbar spondylolisthesis

1. Introduction

Lumbar spondylolisthesis is a common orthopedic disorder primarily caused by lumbar vertebral structural defects or laxity at connection points. It predominantly affects the middle-aged and elderly population, manifesting as intermittent claudication, leg pain, and lower back pain, significantly impacting both physical and mental well-being [1]. Surgical decompression and internal fixation are often employed to treat lumbar spondylolisthesis, stabilizing the spine and improving patient's spinal function. However, relying solely on decompression and internal fixation yields suboptimal results [2]. Research suggests that lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery can achieve better outcomes, including enhanced decompression, reduced pain, quicker postoperative recovery, and decreased inflammatory responses, leading to improved quality of life for patients [3]. However, clinical practice indicates that different surgical instruments can affect surgical trauma and the body's stress response. Therefore, this study aims to further investigate the therapeutic effects of using a monopolar low-temperature plasma electrode and a high-frequency electrotome during lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery, and their impact on patients' inflammatory indicators and quality of life. The medical records of 100 patients were analyzed for comparative purposes, as summarized below.

2. Data and Methods

2.1 General Information

One hundred cases of lumbar spondylolisthesis patients admitted to our hospital from June 2022 to July 2023 were selected for this study. They were randomly divided into a control group and an observation group, with 50 cases in each group. The control group consisted of 29 males and 21 females; their ages ranged from 40 to 69 years with a mean age of

(54.73±4.85) years; the duration of the disease ranged from 0.6 to 4.3 years with a mean duration of (2.36±0.49) years. The observation group included 27 males and 23 females; their ages ranged from 41 to 68 years with a mean age of (54.52±4.68) years; the duration of the disease ranged from 0.4 to 4.1 years with a mean duration of (2.31±0.46) years. There were no statistically significant differences in general information between the two groups ($P>0.05$). Inclusion criteria: ① Diagnosis of lumbar spondylolisthesis confirmed through physical examination, neurological examination, laboratory tests, imaging studies, and electrophysiological tests; ② Underwent lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery without surgical contraindications; ③ Informed about the study and voluntarily participated. Exclusion criteria: ① History of lumbar spinal surgery; ② Coagulation disorders; ③ Cognitive and mental abnormalities.

2.2 Methods

Both groups underwent lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery. The control group used a high-frequency electrotome during surgery, while the observation group used a monopolar low-temperature plasma electrode. The specific surgical steps were as follows:After successful anesthesia, the patient was positioned prone. Routine sterilization with iodine and alcohol was performed on the surgical area, and sterile drapes and cloths were placed. A posterior midline incision of approximately 8 cm was made centered on the target vertebral interspace. The skin, subcutaneous tissue, and deep fascia were sequentially incised, and electrocoagulation was applied for hemostasis. A monopolar low-temperature plasma electrode (device: PSG-60A, electrode: PS-02, both produced by Hunan Jingyi Medical Technology Co., Ltd) / high-frequency electrotome was used to longitudinally incise both sides of the supraspinous ligament, and the paraspinal muscles were separated from the spinous processes and the adjacent bone. This exposed the facet joints on both sides, and needle entry points were chosen on the superior articular processes of the target vertebra. Six pedicle screws (all polyaxial screws) were inserted with appropriate caudal and medial angulation. Fluoroscopy was used to confirm the accurate positioning and appropriate length of the pedicle screws.Using bone rongeurs, a bone dynamic system, and a laminar bone-biting forceps, the spinous process, as well as the lower parts of the left and right laminae of the target vertebra, were excised. A curette was used to separate and remove the ligamentum flavum, exposing the dura mater and nerve roots. Careful dissection was performed, and a nerve dissector was used to gently retract the nerve roots medially, revealing the herniated intervertebral disc of the target vertebra. The neural foramina on both sides became narrower. A No. 15 scalpel was used to make partial posterior annular incisions on both sides, and a nucleus rongeur was used to extract the herniated nucleus pulposus tissue. Saline irrigation was performed to ensure the patency of the nerve root canals, normal nerve root tension, and good dural pulsation.A vertebral osteotome and an endplate scraper were used to scrape the cartilage on the upper and lower endplates of the intervertebral space of the target vertebra, and the endplates were retained and lightly scraped. The intervertebral space was irrigated, and a properly sized intervertebral fusion cage was trial-fitted. The fit and size of the trial cage were confirmed. After removing the trial cage, the scraped bone from the laminae was trimmed into bone chips, and some were placed in the intervertebral space along with an appropriate number of intervertebral fusion cages. The cages were inserted from the right side. An appropriate length of titanium rod was selected and connected to the pedicle screws using conventional techniques. Tail caps were installed and preliminarily tightened. After applying appropriate pressure to the intervertebral space, the pedicle screws were locked. The incision was thoroughly irrigated with a large amount of saline solution. Under fluoroscopy, the position and length of the intervertebral fusion cages and rod system were confirmed to be satisfactory, with good vertebral alignment.After confirming no active bleeding and no cerebrospinal fluid leakage, collagen sponge was placed to cover the dura mater and the bone graft site of the facet joint. One drainage tube was placed and brought out through a separate incision. The incision was sutured layer by layer, and the skin was sutured using a skin stapler. The incision was dressed with sterile dressings. After surgery, both groups of patients received a six-month treatment.

2.3 Observation Parameters

(1) Surgical Indicators: Operation time, intraoperative blood loss.

(2) Inflammatory Indicators: Blood samples were collected before surgery and 6 months after surgery. Enzyme-linked immunosorbent assay (ELISA) was used to measure tumor necrosis factor-alpha (TNF-α) and C-reactive protein (CRP) levels [4].

(3) Pain Levels: Pain intensity was assessed using the Visual Analog Scale (VAS) before surgery and 6 months after surgery. The VAS score ranges from 0 to 10, with scores indicating intense pain (7-10), moderate pain (4-6), mild pain (1-3), and no pain (0) [5].

(4) Quality of Life: The Short Form (Quality of life)-36 (SF-36) questionnaire was used to assess quality of life before surgery and 6 months after surgery. The SF-36 consists of 8 dimensions, with a total score of 100 points. Lower scores

indicate lower quality of life.

2.4 Statistical Analysis

SPSS 19.0 software was used for statistical analysis. Descriptive statistics are presented as mean±standard deviation for continuous data and as [n (%)]) for categorical data. The t-test was used for continuous data, and the chi-square test (x^2) was used for categorical data. ($\bar{x} \pm s$) significance level of P<0.05 was considered statistically significant.

3. Results

3.1 Comparison of Surgical Indicators

The operation time in the observation group was shorter than that in the control group, with a significance of P<0.05. As is shown in Table 1.

Table 1. Comparison of Surgical Indicators ($\bar{x}$ ±s)

Group	Number	Operation Time (min)	Intraoperative Blood Loss (mL)
Control Group	50	105.65±8.93	69.84±5.79
Observation Group	50	88.83±8.01	68.25±5.93
t-value	-	9.915	1.357
P-value	-	0.000	0.089

3.2 Comparison of Inflammatory Indicators

Postoperative TNF-α and CRP levels in the observation group were lower than those in the control group, with a significance of P<0.05. As is shown in Table 2.

Table 2. Comparison of Inflammatory Indicators ($\bar{x}$ ±s)

Group	Number	TNF-α (ng/L)		CRP (mg/L)	
		Preoperative	Postoperative	Preoperative	Postoperative
Control Group	50	23.28±2.74	11.69±1.81	12.95±3.68	9.16±2.42
Observation Group	50	23.51±2.76	9.45±1.73	13.16±3.71	6.27±1.98
t-value	-	0.418	6.326	0.284	6.536
P-value	-	0.677	0.000	0.777	0.000

3.3 Comparison of Pain Levels and Quality of Life

Postoperative VAS scores in the observation group were lower than those in the control group, and SF-36 scores were higher than those in the control group, both with a significance of P<0.05. As is shown in Table 3.

Table 3. Comparison of Pain Levels and Quality of Life ($\bar{x}$ ±s, scores)

Group	Number	VAS		SF-36	
		Preoperative	Postoperative	Preoperative	Postoperative
Control Group	50	7.53±1.47	3.69±0.58	63.47±3.49	76.87±4.75
Observation Group	50	7.69±1.51	2.86±0.49	62.96±3.35	85.73±5.39
t-value	-	0.537	7.730	0.745	8.720
P-value	-	0.593	0.000	0.458	0.000

4. Discussion

Lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery has gained acceptance among an increasing number of patients due to its advantages. It has shown favorable results in the treatment of lumbar spondylolisthesis, effectively relieving or eliminating clinical symptoms, maintaining spinal stability, and enhancing lumbar biomechanical function and performance [6-7]. In the past, this procedure mainly involved the use of a high-frequency electrotome to incise the supraspinous ligament on both sides. However, the high-frequency current from the electrotome could cause significant irritation to the body, leading to greater patient stress responses. Moreover, the use of a high-frequency electrotome was associated with bleeding, oozing, and the production of smoke and odors that limited its clinical application. In contrast, the monopolar low-temperature plasma electrode emits low-temperature plasma radiofrequency energy, achieving coagulation and cutting through the acceleration of ions within a thin plasma layer [at relatively low temperatures (50-100°C)] to disrupt molecular bonds in human tissue [8]. Due to the short range of action of accelerated ions within the plasma layer, the technique allows precise control on the tissue surface in contact with the electrode, offering advantages such as minimal trauma and slight bodily stress responses. The monopolar low-temperature plasma electrode also causes collagen protein to contract, exhibiting certain hemostatic effects. The minimal smoke generated by the monopolar low-temperature plasma electrode ensures a clear surgical field, reducing air pollution in the operating room and contributing to the health of medical staff.

The results of this study demonstrated that the operation time in the observation group was shorter than that in the control group, indicating that the use of the monopolar low-temperature plasma electrode facilitated smoother surgeries compared to the use of a high-frequency electrotome alone. Postoperatively, TNF-α and CRP levels were lower in the observation group than in the control group, indicating that the use of the monopolar low-temperature plasma electrode effectively reduced inflammatory reactions. Furthermore, the postoperative VAS scores were lower and SF-36 scores were higher in the observation group compared to the control group, suggesting that the use of the monopolar low-temperature plasma electrode effectively alleviated patient pain and improved their quality of life.

In conclusion, the treatment outcomes of lumbar spinal canal expansion, decompression, bone grafting, and fusion internal fixation surgery using the monopolar low-temperature plasma electrode were favorable. It effectively shortened operation times, reduced inflammatory responses and pain levels in patients, facilitated postoperative recovery, and enhanced their quality of life. This technique has the potential for wider application.

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