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Muscle gap approach under a minimally invasive channel technique for treating long segmental lumbar spinal stenosis

A retrospective study

Yang Bin, MD[a,*], Wang De cheng, PhD[b], Wang Zong wei, MD[c], Li Hui, PhD[d]

Abstract

This study aimed to compare the efficacy of muscle gap approach under a minimally invasive channel surgical technique with the traditional median approach.

In the Orthopedics Department of Traditional Chinese and Western Medicine Hospital, Tongzhou District, Beijing, 68 cases of lumbar spinal canal stenosis underwent surgery using the muscle gap approach under a minimally invasive channel technique and a median approach between September 2013 and February 2016. Both approaches adopted lumbar spinal canal decompression, intervertebral disk removal, cage implantation, and pedicle screw fixation. The operation time, bleeding volume, postoperative drainage volume, and preoperative and postoperative visual analog scale (VAS) score and Japanese Orthopedics Association score (JOA) were compared between the 2 groups.

All patients were followed up for more than 1 year. No significant difference between the 2 groups was found with respect to age, gender, surgical segments. No diversity was noted in the operation time, intraoperative bleeding volume, preoperative and 1 month after the operation VAS score, preoperative and 1 month after the operation JOA score, and 6 months after the operation JOA score between 2 groups ($P > .05$). The amount of postoperative wound drainage (260.90 ± 160 mL vs 447.80 ± 183.60 mL, $P < .001$) and the VAS score 6 months after the operation (1.71 ± 0.64 vs 2.19 ± 0.87, $P = .01$) were significantly lower in the muscle gap approach group than in the median approach group ($P < .05$). In the muscle gap approach under a minimally invasive channel group, the average drainage volume was reduced by 187 mL, and the average VAS score 6 months after the operation was reduced by an average of 0.48.

The muscle gap approach under a minimally invasive channel technique is a feasible method to treat long segmental lumbar spinal canal stenosis. It retains the integrity of the posterior spine complex to the greatest extent, so as to reduce the adjacent spinal segmental degeneration and soft tissue trauma. Satisfactory short-term and long-term clinical results were obtained.

Abbreviations: CT = computed tomography, JOA = Japanese Orthopedics Association, MRI = magnetic resonance imaging, PLIF = posterior lumbar interbody fusion, TLIF= transforaminal lumbar interbody fusion, VAS = visual analogy score.

Keywords: lumbar spinal stenosis, minimally invasive technique, muscle gap approach

1. Introduction

Surgical treatment is the first choice for lumbar degenerative diseases. The common operation method is intervertebral fusion and internal fixation via intervertebral foramen with a traditional posterior median approach.[1,2] The posterior median approach has long been used as a classical approach for spinal surgery. However, the complications such as more intraoperative bleeding, longer operation time, low back pain[3] caused by edema, and necrosis of the paravertebral muscle gradually emerged. So minimally invasive spine surgery has developed to an important and growing filed which are used in the treatment of degenerative disease, disc herniation, fracture and tumors.[4] For elderly patients with long segmental lumbar spinal stenosis, there are some theoretical advantages in minimally invasive surgery. Some of the approaches of minimally invasive surgery are muscle gap approach for bilateral decompression, minimally invasive transforaminal lumbar interbody fusion (TLIF), transforaminal endoscopic technique, and so on. However, very few reports are present on the muscle gap approach under a minimally invasive channel technique for treating long segmental lumbar spinal stenosis. This study aimed to evaluate the surgical effect of muscle gap approach under a minimally invasive channel technique for treating lumbar spinal stenosis.

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2. Methods

2.1. Inclusion criteria

The inclusion criteria were as follows: Severe low back pain, intermittent claudication, single lower limb symptoms, and more

Figure 1. Preoperative diagnosis was long segmental lumbar spinal stenosis.

than 6 months of formal conservative treatment was invalid. Lumbar computed tomographic (CT) scan and magnetic resonance imaging (MRI) showing lumbar spinal stenosis (Fig. 1). Surgeries performed by the same group of doctors.

2.2. Exclusion criteria

The exclusion criteria were as follows: Bilateral lateral recess stenosis with bilateral lower limb symptoms. Spinal infectious diseases, neoplasms, and severe cardiopulmonary diseases. Lumbar spinal stenosis segments <2.

2.3. Patient recruitment and data collection

Database records of patients treated in our institution for symptomatic lumbar spinal stenosis between September 2013 and February 2016 were retrospectively collected. This article reviewed 68 cases of patients with lumbar spinal stenosis in the Orthopedics Department of Traditional Chinese and Western Medicine Hospital, Tongzhou District, Beijing. This included 35 cases with the muscle gap approach under a minimally invasive channel technique and 33 cases (before this minimally invasive technique was carried out) with the posterior median approach. To be included by this study, all the patients were required to

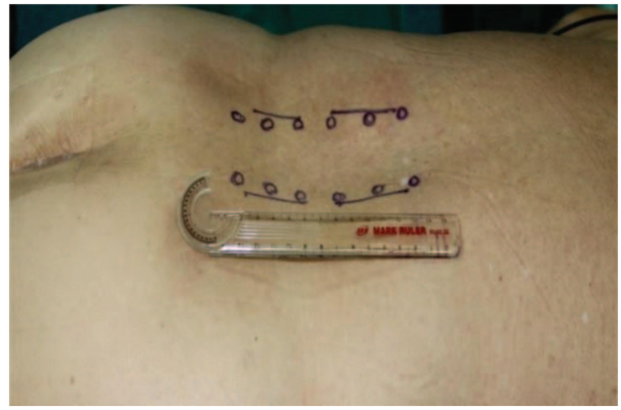

Figure 2. Kirschner wires were arranged parallel and perpendicular in the pedicle, the C-arm fluoroscope determined the position of the pedicle, and the marker point connection line was the incision. Operation incision was about 10 cm.

have complete imaging studies and available clinical data. Complete imaging examination included X-ray, computed tomography (CT), MRI. Complete clinical data included age, gender, surgical treatment, complications, and VAS score questionnaire, the therapeutic efficacy of treatment, using JOA score questionnaires that were completed by the authors or the referring surgeries who examined and treated each patient. The patients were further categorized into 2 groups according to the time before and after this minimally invasive technique was carried out. The operation time, intraoperative bleeding volume, postoperative wound drainage, preoperative and postoperative pain degree (VAS pain score), and JOA spinal function score were recorded and compared by reviewing medical records. The approval from the hospital medical ethics committee and consent of patients were obtained.

2.4. Operative procedures

Operation method of muscle gap approach under a minimally invasive channel group: after the successful administration of anesthesia, the patient was placed on the surgical table in prone position. The bilateral pedicle was located with a C-arm X-ray machine and marked on the body surface. The line of ipsilateral upper and lower pedicle midpoint was the surgical incision line (Fig. 2). On the symptomatic side, the paraspinal muscle close to the spinous process was stripped off to show the lamina and facet joint. The conventional pedicle screw canal was prepared via pedicle to vertebral body (Fig. 3 A and B). The bleeding was

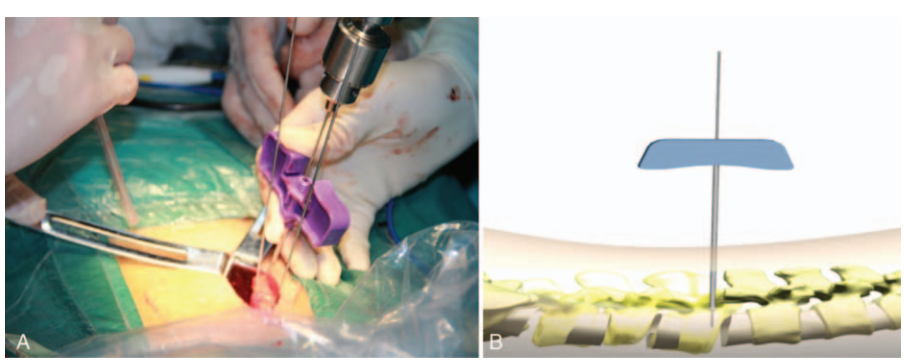

Figure 3. (A) According to the C-arm position, Kirschner wires were drilled via pedicle to vertebral body. Each screw canal was inserted into a guide pin. (B) The positions of guide pins were tested with the C-arm X-ray machine, and then tapped.

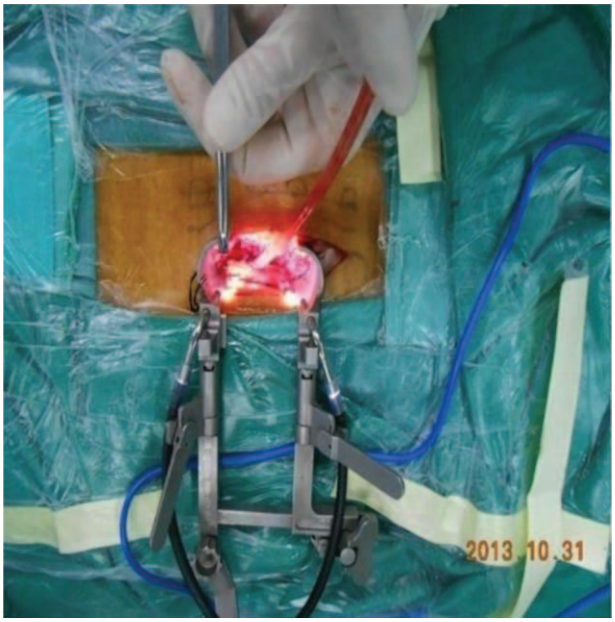

Figure 4. One side was discontinuous small incisions. The pedicle nails were screwed along the Kirschner wire.

temporarily stopped using bone wax. The expansion tube was imported step by step, the minimally invasive channel[5–7] (Fig. 4) installed matched with a cold light source that provided a new generation of wide viewing angle for minimally invasive spine operations. The amount of bleeding was less compared with open surgery. Under a minimally invasive channel, part of the facet joint was removed, two-thirds lower lamina was cut with bone forceps, hypertrophic and tough yellow ligament was removed, lateral recess was decompressed, and lumbar disk herniation and nerve root were explored. The nucleus pulposus, fiber ring, and end plate were removed. The autologous bone fusion cage was hammered into the intervertebral space about 8 mm to the posterior margin of the vertebral body. On the other side, the facet joints were exposed through the muscle gap of multifidus and longissimus,[8] which played a role in controlling the rotation and shear force of the spinal segments. A conventional pedicle screw canal was prepared via pedicle to vertebral body. Each screw canal was inserted into a guide pin. The positions of guide pins were tested with the C-arm X-ray machine. Then, the polyaxial pedicle screws were tapped and implanted through the guide pins (Fig. 5). The connecting rod (Fig. 6) of suitable length was arranged in the "U"-shaped groove of the screw.

Operation method of posterior median approach group: This group adopted the traditional posterior lumbar interbody fusion (PLIF) operation method. The patient was placed on the surgical table in prone position. The posterior median incision was used to remove the lamina, spinous process, and part of the facet joints. Decompression of lateral recess, removal of herniated intervertebral disk, placement of interbody fusion cage, fixation of pedicle screw, and connection of rod were done. A drainage tube was indwelled and the incision was sutured layer by layer.

2.5. Postoperative management

According to the nerve symptoms after removing the drainage tube, hormone and dehydration drugs were used for 3 days, and preventive antibiotics were used for 24 to 48 hours. Three days after the operation, the patients could walk with the waist corset. Outpatient follow-up was continued for 12 to 15 months. The patients wore waist circumference 1 month after the operation, and the visual analog scale (VAS) score and Japanese Orthopedics Association (JOA) score were evaluated. The X-ray films (Fig. 7 A and B) were taken 3 months after the operation, and the waist circumference was removed. The VAS score and JOA score were evaluated 6 months after the operation. The lumbar X-ray films were taken 12 months after the operation.

2.6. Statistical analysis

All data were statistically analyzed using SPSS statistical software version 13.0 (SPSS, Inc., Chicago, IL). Data were expressed as mean ± standard deviation ($x \pm s$), and analyzed using *t* test and

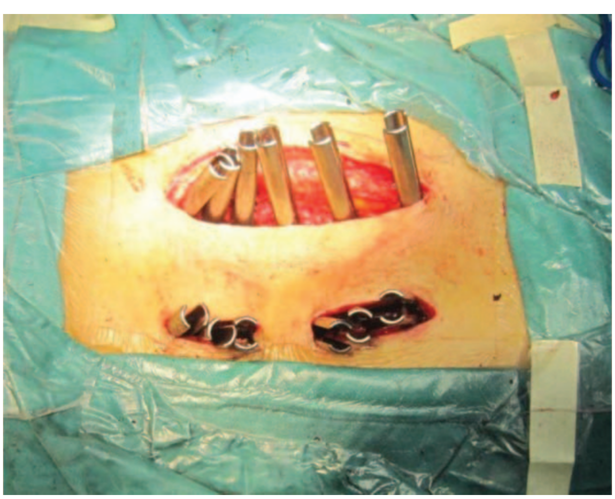

Figure 5. Connecting rod of suitable length was arranged in the "U"-shaped groove of the screw. The connecting rod was inserted through the subcutaneous tunnel.

Figure 6. On the symptomatic side, the minimally invasive channel was matched with a cold light source. Under a minimally invasive channel, the improved TLIF surgical procedure was adopted.

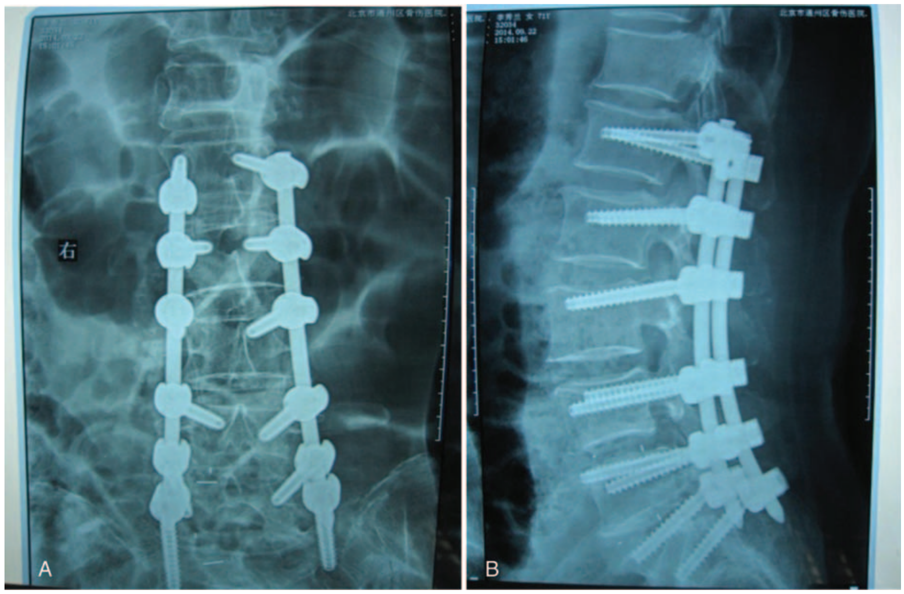

Figure 7. (A and B) X-ray after operation.

χ^2 test to compare categorical variables between the 2 groups. The confidence interval (CI) of 95% and the level of significance for this study was 5%. $P < .05$ difference was statistically significant.

3. Results

From September 2013 to December 2014, 33 cases with long segmental lumbar spinal stenosis were treated with the traditional posterior median approach; 4 patients were excluded for heart diseases, tumor and infectious factor; 45 patients with only 1 segment undergoing surgery were excluded. From December 2014 to February 2016, 35 cases were treated with the muscle gap approach under a minimally invasive channel technique; 5 patients were excluded for severe scoliosis and heart diseases; 63 patients with 1 or 2 segments undergoing surgery were excluded (Table 1). All patients were followed up. Both groups underwent

Table 1

A flow of subject selection.

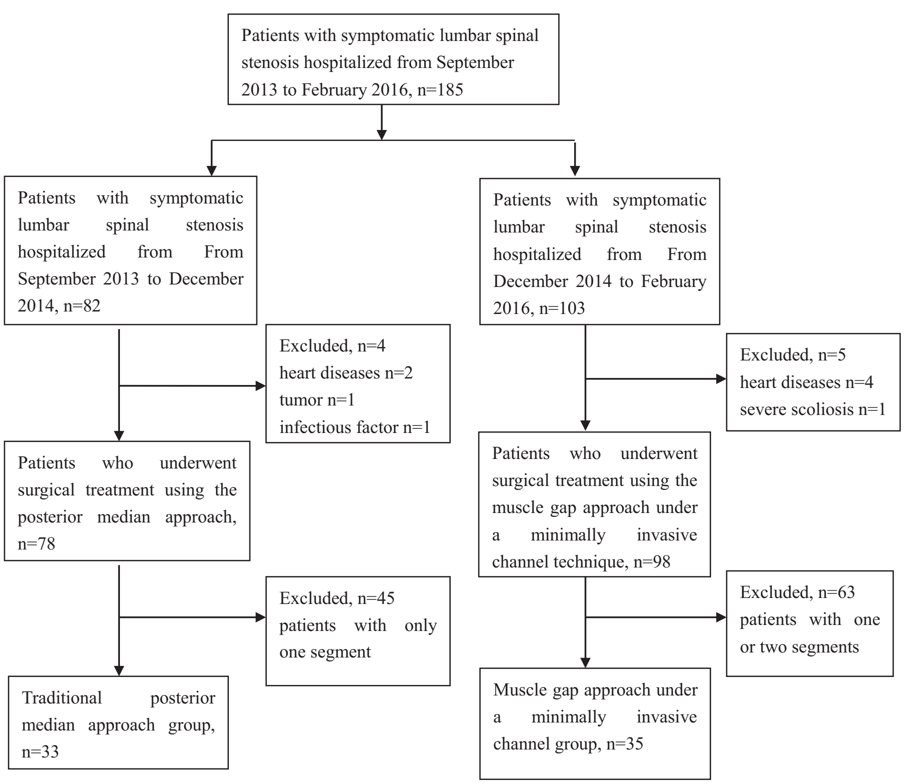

Table 2

Comparison of clinical data of patients between 2 groups before the operation.

Item	Muscle gap approach under a minimally invasive channel group	Traditional posterior median approach group	*P*
Male/female	11/24	14/19	.306
Age, y	65.33 ± 5.64	64.36 ± 6.55	.694
2 Lesion of segments	0	11	
3 Lesion of segments	24	11	
4 Lesion of segments	7	7	
5 Lesion of segments	4	4	
Number of segments			.951
L1/2 segment	6	6	
L2/3 segment	20	13	
L3/4 segment	35	26	
L4/5 segment	35	33	
L5/S1 segment	24	25	
Surgical segments			.808

Table 3

Comparison of operation time, intraoperative bleeding volume, postoperative wound drainage, VAS score, and JOA score of patients between 2 groups before and after the operation (x ± s, score).

Evaluation project	Muscle gap approach under a minimally invasive channel group	Traditional posterior median approach group	*P*
Operation time, min	220.50 ± 39.59	201 ± 53	.09
Intraoperative bleeding volume, mL	532 ± 264	423 ± 277	.11
Postoperative wound drainage, mL	260.90 ± 160	447.80 ± 183.60	<.001
Preoperative VAS pain score	5.19 ± 2.16	4.86 ± 1.56	.41
VAS score 1 mo after the operation	3.19 ± 0.98	3.29 ± 1.15	.77
VAS score 6 mo after the operation	1.71 ± 0.64	2.19 ± 0.87	.01
Preoperative JOA score	10.52 ± 2.50	12.00 ± 2.32	.06
JOA score 1 mo after the operation	18.43 ± 1.75	19.19 ± 1.83	.18
JOA score 6 mo after the operation	20.86 ± 2.27	21.95 ± 1.86	.09

JOA = Japanese Orthopedics Association, VAS = Visual analogy score.

decompression of lumbar spinal canal, intervertebral disk removal, cage implantation, and pedicle screw fixation. No patient or family refused to participate.

3.1. Demographic and preoperative data

Muscle gap approach under a minimally invasive channel group: the clinical data of 35 cases were reviewed. Among them, 11 males and 24 females, the average age was 65.3 years. There were 24 cases with 3 segments, 7 cases with 4 segments, 4 cases with 5 segments, 6 cases with L1/2 segment, 20 cases with L2/3 segment, 35 cases with L3/4 segment, 35 cases with L4/5 segment, 24 cases with L5/S1 segment.

Traditional posterior median approach group: the clinical data of 33 cases were reviewed. Among them, 14 males and 19 females, the average age was 64.4 years. There were 11 cases with 2 segments, 11 cases with 3 segments, 7 cases with 4 segments, 4 cases with 5 segments, 6 cases with L1/2 segment, 13 cases with L2/3 segment, 26 cases with L3/4 segment, 33 cases with L4/5 segment, 25 cases with L5/S1 segment.

No significant intergroup difference was found with respect to age ($t=0.395$, $P=.694$), sex ($\chi^2=1.048$, $P=.306$), number of segments ($\chi^2=0.349$, $P=.951$), or surgical segments ($\chi^2=1.605$, $P=.808$) (Table 2).

3.2. Clinical outcomes

No diversity was noted in the operation time, intraoperative bleeding volume, preoperative and 1 month after the operation VAS score, preoperative and 1 month after the operation JOA score, and 6 months after the operation JOA score between 2 groups ($P>.05$) (Table 3). The 2 groups of preoperative and postoperative VAS score and JOA score were statistically significant (Table 4), indicating that both procedures were effective for long segmental lumbar spinal stenosis. Both improved the quality of life of patients.

The differences between 2 groups in the amount of postoperative wound drainage and the VAS score after 6 months of operation were statistically significant ($P<.05$) (Table 3). In the muscle gap approach under a minimally invasive channel group, the average drainage volume was reduced by 187 mL, and the average VAS score 6 months after the operation was reduced by an average of 0.48. Compared with the traditional operation, the muscle gap approach under a minimally invasive channel technique with less postoperative drainage greatly reduced the risk of blood transfusion in the case of blood shortage and achieved the same effect of traditional operation. Moreover, the long-term low back pain was relieved to a greater extent.

3.3. Complications

No severe complications, such as screw fracture, postoperative mortality, and infection cases, were noted in both groups. The occurrence of perioperative morbidities and late complications were documented (Table 5). There was no statistical significance between 2 groups.

Muscle gap approach under a minimally invasive channel group: perioperative morbidity was noted in 6 patients (17.1%). One patient

Table 4

Comparison of VAS score and JOA score of intra-group patients before and after the operation (x ± s, score).

Evaluation project	Preoperative VAS pain score	VAS score 1 mo after the operation	*P*	Preoperative JOA score	JOA score 1 mo after the operation	*P*	JOA improvement rate 6 mo after the operation	Excellent and good rate of JOA improvement, %
Muscle gap approach under a minimally invasive channel group	5.19 ± 2.16	3.19 ± 0.98	<.001	10.52 ± 2.50	18.43 ± 1.75	<.001	56.21 ± 8.83	100
Traditional posterior median approach group	4.86 ± 1.56	3.29 ± 1.15	<.001	12.00 ± 2.32	19.19 ± 1.83	<.001	58.60 ± 9.17	100

JOA = Japanese Orthopedics Association, VAS = visual analogy score.

Table 5

Comparison of surgical methods with respect to perioperative morbidities and late complications.

	Muscle gap approach under a minimally invasive channel group (n=35)	Traditional posterior median approach group (n=33)	*P*
Perioperative morbidity (number of patients)	6 (17.1%)	4 (12.1%)	.771
Cerebrospinal fluid leakage	1	1	
Epidural hematoma	1		
Pneumonia		2	
Urinary difficulty	2	1	
Nerve traction injury	1		
Fat liquefaction	1		
Late complications (number of patients)	1 (2.9%)	2 (6.1%)	.99
recurrence	1		
Screw loosening		1	
Cage displacement		1	
Reoperation	3 (8.6)	1 (3.0%)	.371

underwent reoperation due to postoperative epidural hematoma. Fat liquefaction was noted in 1 case, and the wound was healed after suture in the operation room under anesthesia again. One case of nerve root traction was present. The symptom of dorsal extension weakness of the toe disappeared 4 weeks after the operation. One patients (2.9%) developed late complications who underwent reoperation due to recurrence of symptoms with disc herniation.

The traditional posterior median approach group: perioperative morbidity was noted in 4 patients (12.1%). Two patients (6.1%) developed late complications. The intervertebral cage was moved forward in 1 case. The patient without neurological symptoms did not receive special treatment. One case of peripheral sacral one pedicle nail appeared X-ray radiolucent zone which showed screw loosening. After bone graft through the screw and bicortical pedicle screw fixation, the case achieved successful interbody fusion after 3 months.

However, it is not reasonable to compare the perioperative morbidity and late complication rate between 2 groups because most of the items of complications are different.

4. Discussion

Wiltse et al[9–11] first proposed the muscle gap approach between multifidus and longissimus, which could be used as a surgical approach of the pedicle screw insertion in nondecompression of spinal canal. In the present study, the muscle gap approach was extended, and the long segmental lumbar spinal canal decompression and pedicle screw fixation were performed using the muscle gap approach under a minimally invasive channel technique. The skin incision was made next to the midline by 3 cm. A natural cleavage plane was present between multifidus and longissimus; blunt separation with a finger could directly expose the needle point of vertebral pedicle in the operation. The insertion point was similar to the extension of the angle of pedicle screw insertion, and the muscle tissue was always slack during the operation. The Kirschner wire was inserted into the vertebral pedicle and the hollow pedicle nail was screwed down the Kirschner wire. Most scholars believed that the percutaneous implantation of pedicle screws could reduce complications and was a safe method.[12,13] Meanwhile, doctors need to be familiar with the spinal anatomy and the touch technique; those operating for the first time could use the microretractor to expose the needle point of a vertebral pedicle. Blunt separation between the muscle gap could effectively protect the nerve and blood supply of the multifidus. Imaging the Kirschner wire with a standard C-arm fluoroscope before the placement of the screw into vertebral pedicle could ensure the accuracy of the screw fixation. According to preoperative CT, MRI data, and clinical signs, it was feasible to resect the upper and lower margins of adjacent segment vertebral lamina. The yellow ligament was removed to expand the volume of the spinal canal in the nondecompression side if the yellow ligament extensively hypertrophied to reduce the volume of the vertebral canal.

4.1. Surgical technique and operation experience of the muscle gap approach

Positioning was the key to the insertion of the pedicle screw through the muscle gap. The line of the middle point of the pedicle was the operative incision line. Patients after anesthesia were in the prone position. Kirschner wires were arranged parallel and perpendicular in the pedicle, the C-arm fluoroscope determined the position of the pedicle and the body surface projections of vertebral pedicles were marked. The marker point connection line was the incision. The nondecompression side incision could be divided into several discontinuous 2-cm long small incisions. Pedicle screws of 2 adjacent segments were implanted in each incision. One end of the connecting rod was a bullet head. The "U"-shaped groove of the pedicle screw was adjusted to make it parallel to the insertion of the connecting rod through the subcutaneous tunnel. A small incision could achieve the aesthetic effect, but it was not the main idea of the minimally invasive technique. The retention of the posterior spinal complex was the essence of this technique. This study followed the principles of minimally invasive spine surgery[14]: reducing the trauma of the posterior vertebral muscle groups, limiting the total amount of bone removal to minimize the degree of spinal instability.

4.2. Research results and the meaning of muscle gap approach under a minimally invasive channel technique

Traditional posterior median approaches require extensive muscular and ligamentous disruption resulting in decreased spinal stability and associated morbidities.[15] The minimally invasive channel that was matched with a cold light source provided a wide viewing angle, making the operative visual field more clear. Through the muscle gap of multifidus and longissimus, persistent stripping and stretching of paravertebral muscles was avoided. Paraspinal muscle groups are wrapped tightly around by thick and tough muscle fascia. After a long time of strong traction, postoperative edema leads to ischemia. Compartment syndrome can occur in postoperative muscle atrophy, and scar healing of multifidus and vertebral lamina.[16,17] The characteristics of blood supply, metabolism, and innervation of the paraspinal muscle make the process last for a long time. These factors are the important reasons for the intractable low back pain after the operation.[3] For the application of this minimally invasive technique, lumbocrural pain (VAS score 6 months after the operation) was significantly lower in the muscle gap approach under a minimally invasive channel group. Fan et al[18] reported that 28 cases of lumbar spinal stenosis were treated by decompression and interbody fusion with the muscle gap approach under a minimally invasive channel technique, and the excellent and good rate was 92.8%. In the present study, the JOA improvement rate 6 months after the operation was 56.21 ± 8.83%. The excellent and good rate was 100%.

The posterior median approach group adopted PLIF surgical procedure for the removal of lamina, spinous process, and part of the zygapophyseal joints. The lumbar spinal canal stenosis is caused mainly due to hyperplasia, hypertrophy, and cohesion of zygapophyseal joints, leading to the narrowing of the posterior wall of nerve root canal and compression of the nerve root. Prolapse of lumbar intervertebral disk and hypertrophy of ligamentum flavum cause central canal stenosis. However, the lamina[3] does not produce compression symptoms. Compared with the posterior median approach group, the muscle gap approach under a minimally invasive channel group adopted the improved[19] TLIF method, which was considered a safe and effective method.[20,21] For lumbar fusion, part of the zygapophyseal joints was needed to be removed, excising anterior and posterior edges rather than the whole lamina and retaining the spinous process, interspinal ligament, and supraspinous ligament. The muscle gap approach under a minimally invasive channel technique protected the posterior spine complex stability to the greatest extent so as to reduce the degeneration of the operation and the adjacent segments. Postoperative patients can gain early activity and functional recovery. Satisfactory short-term and long-term clinical results were obtained.

Currently, the surgical literature on the muscle gap approach under a minimally invasive channel technique were mostly discussed in the application of single segmental lumbar spinal stenosis, and seldom in long segmental lumbar spinal stenosis. The segment of degenerative lumbar spine in elderly patients is long, and the factor is complex. If the selective segment is fixed, the adjacent segment will degenerate quickly and the second surgery will increase the risk and the cost. Therefore, the treatment strategy in the present study was long segmental pedicle screw fixation to ensure long-term efficacy. The operations were completed by the same group of doctors, which ruled out the interference of the potential factors such as the surgeon's habit and operation conditions.

4.3. Limitation

The study sample was small, the control was nonsynchronized, and the follow-up time was short. The minimally invasive surgical technique requires higher operating techniques and has a certain learning curve. With the increase in the number of operation cases, the operation time was shortened gradually and became similar to the traditional operation mode. The range of indications was narrow, lumbar pain with single lower limb symptoms.

5. Conclusion

To sum up, compared with the traditional posterior median approach, the muscle gap approach under a minimally invasive channel technique could reduce the paraspinal muscle ischemia and necrosis, retain the posterior spine complex, reduce the postoperative wound drainage, nail easily and accurately, and gain satisfactory long-term curative effect. It could also reduce the occurrence of low back pain after the operation. Therefore, this technique conforms to the concept of minimally invasive and is an effective method for treating long segmental lumbar spinal canal stenosis.

Acknowledgments

This work was performed by the surgery team of Orthopedics Department of Traditional Chinese and Western Medicine Hospital in Tongzhou District, Beijing, China. This study was approved by the ethical committee of the hospital, and the consent forms were obtained from all patients.

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