Original paper

Folia Neuropathologica

Analysis of injury and pain scores during fusion surgery for multisegmental lumbar spinal stenosis in elderly patients

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Folia Neuropathol 2022; 60 (3): 355–361 *DOI: https://doi.org/10.5114/fn.2022.118801*

Abstract

Introduction: *Lumbar stenosis has become a common disease. Controversies exist regarding fusion surgery.*

Material and methods: *The patients were divided into groups per the method of fusion received: the posterolateral fusion group (group P) and the intervertebral fusion group (group I). The patients were further divided into groups based on the number of fusion segments: the 2-segment group (P2 and I2), the 3-segment group (P3 and I3), and the 4-segment group (P4 and I4). The operative time, intraoperative blood loss, blood transfusion volume, and postoperative drainage volume were summarized. In particular, wound healing appearance and management were observed.*

Results: *The operation time and blood transfusion volume of the P2 and P3 groups were significantly less than those of the I2 and I3 groups ($p < 0.05$). The postoperative drainage volume of group I4 was less than that of group P4 ($p < 0.05$). Postoperative numeric rating scale (NRS) scores of P2 and P3 groups were lower than those of I2 and I3 groups ($p < 0.05$), while the NRS scores of P4 group were higher than those of I4 group ($p < 0.05$).*

Conclusions: *Posterolateral and intervertebral fusion techniques can be used in the surgical treatment of elderly patients with lumbar spinal stenosis. The posterolateral fusion method should be used when three or fewer segments require surgery. The intervertebral fusion method should be used when four segments require surgery.*

Key words: *elderly patient, lumbar spinal stenosis, operation, intervertebral fusion, posterolateral fusion.*

Introduction

Lumbar spinal stenosis (LSS) refers to the narrowing of the anteroposterior and transverse diameters of the spinal canal, resulting in compression of the dural sac, spinal cord, or nerve roots, thus leading to a series of neurological disorders [6]. The disease is mostly caused by lumbar degenerative diseases, such as intervertebral disc degeneration, vertebral facet joint hyperplasia, hypertrophy and cohesion, ligamentum flavum hypertrophy and ossification, which can lead to different degrees of lumbar spinal stenosis. Lumbar spinal stenosis occurs in the elderly. Lumbar spinal stenosis is the leading cause of spinal disease requiring surgery in patients over 65 years of age [18]. Therefore, it is urgent to find an effective treatment for the elderly.

In recent years, the incidence rate of intervertebral canal stenosis has been increasing, which has a serious impact on the quality of life of the middle-aged and elderly [13]. When conservative treatment fails, patients are often referred for surgery. The common surgical treatment methods are traditional open laminectomy, lumbar fusion and interspinous device. In the above common clinical treatment methods, clinical evidence has shown that traditional open laminectomy has the disadvantages of large trauma, more intraoperative bleeding and postoperative paravertebral muscle weakness or atrophy [12]. As for the interspinous device, although there is evidence that patients may have clinical benefits [17], due to the insufficient sample size, large-scale trials are still needed to supplement the evidence.

The concept of interbody fusion was first proposed by Cloward [2], and then Lin improved it [14]. This

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treatment method has been increasingly popular in the clinic [26]. Lumbar interbody fusion (LIF) has excellent fatigue resistance and fusion rate [29], which is considered to be the first choice for the treatment of lumbar degenerative diseases to reconstruct lumbar stability. The posterior lumbar interbody fusion (PLIF) is a classic method, which is recognized as the gold standard for the treatment of LSS [4]. Posterolateral fusion (PLF) is also a common choice among various techniques that can be used to treat lumbar spondylolisthesis. The advantages of this method are that it is relatively simple and quick, does not require disc management, has less bleeding, and reduces the possibility of the spinal cord and nerve root injury. But its disadvantages are also obvious [10]: in the process of bone grafting, the treatment of the bone graft bed is relatively difficult. The area where the graft is performed is on the tension side of the spine rather than on the pressure side, which is likely to result in a fusion failure. Intervertebral fusion is another effective treatment of choice for symptomatic lumbar instabilities. The intervertebral fusion has the advantage of a high fusion rate and high safety, and there are also shortcomings, such as difficulty and high treatment costs [19].

The purpose of our study is to observe the excellent effect of fusion while reducing local trauma and postoperative pain response and to analyse and summarize the operation methods of bone graft fusion.

Material and methods

General information

Data were collected from 173 elderly patients with lumbar spinal stenosis admitted to our department from 2013 to 2019. The patients were divided into groups based on the type of fusion operation received: the posterolateral fusion group (group P) and the intervertebral fusion group (group I). Patients are further divided into groups according to the number of fusion segments: 2-segment group (P2 and I2 groups), 3-segment group (P3 and I3 groups), and 4-segment group (P4 and I4 groups). This research has been approved by the institutional review board (IRB) of the authors.

Inclusion and exclusion criteria

Surgical indications included: 1) patients diagnosed with multi-segment lumbar spinal stenosis and lumbar spine instability before surgery or segments that may be unstable after surgery, 2) difficulty walking and intermittent claudication, 3) recurrent low back pain impeding normal life, 4) the appearance of cauda equina neurosis symptoms, and 5) the failure of 3 months of conservative treatment. Exclusion criteria were: 1) cervical or thoracic spinal stenosis diagnoses, 2) obvious abnormal function of lower limb joints, 3) infection or tumour in the spinal canal, 4) associated varicose veins, vasculitis, etc., and 5) serious medical diseases not suitable for surgical operation.

Surgical methods

All surgeries were performed by the same group of senior doctors. In all groups, general intravenous combined anaesthesia was used for anaesthesia, the posterior midline approach was used in surgery, and pedicle screw internal fixation was performed. During the operation, all or part of the vertebral lamina and ligamentum flavum within the narrow range were resected. In general, the volume of the spinal canal at the narrow segment became smaller and local tension increased. It was necessary to pay attention to the protection of the dura sac while it was exposed. The nerve root was found and fully decompressed. The end of decompression was marked by the absence of mechanical compression on the nerve root and the ease with which it was moved.

Preparation of autogenous bone

The autogenous bone used for the graft was obtained from the spinous process or lamina excised during the operation. The soft tissue or cartilage on the surface of the bone was removed, and a piece approximately 0.1 cm^3 in size was cut for use. Prolonged compression of skin and muscle tissue should be avoided as much as possible. Haemostasis should be thorough during the operation and bipolar coagulation should be used as long as possible.

Intervertebral fusion group (Group I)

The nerve root was gently led toward the inside and was properly protected. The inferior articular process of the upper vertebral body, or the superior articular process of the lower vertebral body, were removed according to the surgical requirements. The lateral recess was enlarged. The intervertebral disc and cartilage endplate were removed while the subchondral bone was protected from damage. The fusion cages used were made of hollow polyether ether ketone (PEEK) material. Sufficient amounts of autogenous bone graft were used to fill the anterior intervertebral space and the fusion cage. The PEEK fusion cage is a single piece and is generally placed diagonally forward on the side with severe symptoms or on the concave side with degenerative scoliosis.

Posterolateral fusion group (Group P)

The intervertebral joints were retained, and the lateral recesses were expanded stealthily in posterolateral fusion operations. The posterior side of the transverse processes was exposed and decorticated with a ball drill. The intervertebral facet articular cartilage was destroyed. Autogenous bone grafts were placed on the surfaces of the transverse processes and in the spaces of the intervertebral joints on both sides.

Postoperative management

The patients were treated with antibiotics for 3-5 days and 10 mg dexamethasone for 3 days. The patients were treated with neuronutrition drugs, dehydrating agent and hormone according to the condition (hormone and dehydrating agent were routinely used, including dexamethasone sodium phosphate injection (10 mg, IVGTT, qd, 3d) and mannitol (125 ml, IVGTT, bid, 3d) or furosemide (40-60 mg, IVGTT, bid, 3d). In case of decreased spinal cord function, methylprednisolone (500-1000 mg, IVGTT) rapid impact can be considered. Neurotrophic drugs mainly include ganglioside, nerve growth factor, adenosine cobalamin, etc., mainly considering the economics of drugs and the acceptance ability of patients, not routine application). The patients were re-examined in the anteroposterior and lateral position of lumbar vertebra after operation, and then they were put on the brace to move down the ground. They continued to wear the brace when they moved down the ground after discharge. During the period, they actively carried out the functional exercise of lumbar and dorsal muscles.

Efficacy evaluation indicators

The operative time, intraoperative blood loss, blood transfusion volume, and postoperative drainage volume were recorded. Postoperative wound healing and the numeric rating scale (NRS) for pain preoperatively, at 2 weeks, 3 months, and at the final follow-up after surgery were also recorded. The NRS was composed of 11 numbers (0 through 10), with 0 indicating no pain. The larger the number was, the stronger the pain, with 10 being the most severe. The Oswestry disability index (ODI) and the Japanese Orthopedic Association (JOA) scores were recorded before surgery and at the final postoperative follow-up [24].

Main outcome measures include operative time, intraoperative blood loss, blood transfusion, postoperative drainage, postoperative wound healing, and NRS score before surgery, 2 weeks, 3 months after surgery, and at the end of follow-up; secondary outcome measures include ODI score and JOA score before and at the end of follow-up.

Statistical analysis

Measurement data were presented as $\bar{x}$ ± SD. SPSS 19.0 was used for statistical analysis. A χ^2-test was used for general data (gender, age, and lesion segment) to determine whether there was comparability between the groups. An independent sample *t*-test was used for the mean comparison between the groups. The difference significance level was $p < 0.05$.

Results

Subject characteristics

There were 84 patients in group P (32 males and 52 females, with an age range of 60 to 83 years old and an average age of 67.63 ±5.86 years old) and 89 patients in group I (40 males and 49 females, with an age range of 60 to 84 years old and an average age of 67.05 ±5.47 years old). These two groups were subdivided into the 2-segment group (group P2 and group I2), the 3-segment group (group P3 and group I3), and the 4-segment group (group P4 and group I4) according to the number of segments fused in surgery. The number of cases in the P2, P3 and P4 groups were 25, 33 and 26, respectively. The number of cases in groups I2, I3 and I4 were 52, 29 and 8, respectively. There was no significant difference in the statistical analysis of general information, such as gender, age, and surgical segments of the patients, so it was comparable.

Comparison of related indexes in the perioperative period

As is demonstrated in Table I, the operative time of groups P2 and P3 was lower than in groups I2 and I3 ($p < 0.05$), and the difference between group P4 and group I4 was not statistically significant. Intraoperative blood loss in group P2 was less than in group I2 ($p < 0.05$), and there were no statistically significant differences between groups P3 and I3 or between groups P4 and I4. The blood transfusion volume of groups P2 and P3 was less than in groups I2 and I3, respectively ($p < 0.05$), and the difference between group P4 and group I4 was not statistically significant. The postoperative drainage volume of group I4 was less than in group P4 ($p < 0.05$), and the differences between groups I2 and P2 and groups I3 and P3 were not statistically significant.

Comparison of functional indicators and fusion before and after operation

There were no perioperative deaths. In the follow-up period of 13 to 38 months (an average of 15.8 months), there were 44/173 cases (25.4%) with incision and surrounding soft tissue complications, including 32/84 cases (37.9%) in group P and 12/89 cases (13.3%) in group I (Figs. 1, 2). There were significant differences between the two groups ($p < 0.05$). These complica-

Table I. Surgical indicators between the two fusion methods with same segments

	Operative time (h)			Intraoperative blood loss (ml)			Blood transfusion volume (ml)			Drainage volume (ml)		
P	P2 *n* = 25	P3 *n* = 33	P4 *n* = 26	P2 *n* = 25	P3 *n* = 33	P4 *n* = 26	P2 *n* = 25	P3 *n* = 33	P4 *n* = 26	P2 *n* = 25	P3 *n* = 33	P4 *n* = 26
	2.32 ±0.41	2.68 ±0.46	3.32 ±0.45	284.40 ±95.96	442.42 ±188.38	505.77 ±188.85	120.00 ±258.20	551.52 ±438.84	769.23 ±347.30	662.40 ±227.89	974.85 ±345.63	1182.31 ±361.20
I	I2 *n* = 52	I3 *n* = 29	I4 *n* = 8	I2 *n* = 52	I3 *n* = 29	I4 *n* = 8	I2 *n* = 52	I3 *n* = 29	I4 *n* = 8	I2 *n* = 52	I3 *n* = 29	I4 *n* = 8
	2.55 ±0.52	3.11 0.58	3.38 ±0.66	407.69 ±239.77	531.38 ±385.30	562.50 ±306.77	392.31 ±488.23	827.59 ±582.42	1062.50 ±515.30	685.58 ±299.02	933.62 ±266.322	875.63 ±147.30
p	0.04	0.002	0.830	0.016	0.265	0.633	0.011	0.042	0.072	0.708	0.599	0.027

Independent sample t-test was used for inter-group comparison, and the significance level of difference was 0.05.

Fig. 1. The patient, a 62-year-old man with multisegmental lumbar spinal stenosis, underwent lumbar spinal decompression, posterolateral fusion and internal fixation in 2018. Lumbar MRI was reviewed 1 month after the surgery still showed obvious soft tissue oedema and inflammatory response within the incision.

Fig. 2. The patient, a 62-year-old man, had 3-segment lumbar spinal stenosis (stenosis) and lumbar instability (instability). Lumbar spinal canal decompression and intervertebral fusion surgery were performed in 2014. After the operation, the lumbar vertebral body sequence returned to normal, and the stenosis was effectively relieved.

tions mainly included superficial incision skin ulcers (8 cases), subcutaneous dropsy (11 cases), skin blackening and hardening (10 cases), and pain around the incision (15 cases). Debridement and dressing change should be given for treatment of these complications. No bacterial infection was found in the incision tissue or exudate cultures during hospitalization. Acute pain around the incision was treated with nerve blocks. As shown in Table II, postoperative NRS pain scores were significantly lower than those before surgery ($p < 0.05$). At 2 weeks and 3 months after surgery, the NRS scores of groups P2 and P3 were lower than those of groups I2 and I3 ($p < 0.05$), and those of group P4 were higher than those of group I4 ($p < 0.05$).

There were significant differences in ODI and JOA scores preoperatively and postoperatively ($p < 0.05$) but there were no statistically significant differences between group P and group I at the end of follow-up (Table III). This may indicate that the two fusion methods have no direct impact on the final surgical effect.

Discussion

In older populations, lumbar spinal stenosis can cause obvious symptoms. The general symptoms of lumbar spinal stenosis are complicated in nature and long in duration, while medically there are more affected segments, slower healing times, and limited surgical opportunities with these patients. Most patients require surgical intervention, especially when non-operative treatment has failed for 6 months or more, or if there is nerve damage progression or cauda equina syndrome. Operative treatment is superior to non-operative treatment in pain reduction and in improved lower limb functional recovery [8,16,21,28]. Decompression can effectively remove the degenerative bone or fibrous tissues that lead to spinal canal stenosis, which is key to the success of the operation.

Rigid internal fixation and correct selection of bone graft materials can improve the fusion rate

Internal fixation provides immediate stability of the spine. Fusion can maintain stability of the spine for a long time and may help prevent any recurrence of spinal stenosis [1]. On the premise of excluding osteoporosis, a longer bed rest time can subjectively ensure the effective braking of patients and create conditions for bony fusion. It should be noted that moderate movement of limbs should be closely combined with bed rest.

At present, the most common methods of posterior fusion include posterolateral fusion, PLIF, and TLIF [15,20]. It is generally believed that the fusion efficiency in the intervertebral method is higher than in the posterolateral method when the size and mass of the bone graft is suitable enough [25]. A major determinant of successful fusion is the bone graft [22]. The materials of bone fusion include autogenous bone [9], bone marrow extract, etc. Autologous bone has good tissue compatibility and can reduce the cost of patients [27].

Table II. Numeric rating scale (NRS) scores between the two fusion methods with same segments at different times

	Preoperative			Postoperative 2 weeks			Postoperative 3 months			Final follow-up		
P	P2	P3	P4	P2	P3	P4	P2	P3	P4	P2	P3	P4
	6.48 ±0.82	6.27 ±0.67	6.39 ±0.85	3.52 ±0.65	5.06 ±0.61	5.54 ±0.71	2.92 ±0.57	3.79 ±0.74	4.58 ±0.64	1.80 ±0.65	2.58 ±0.56	2.27 ±0.45
I	I2	I3	I4	I2	I3	I4	I2	I3	I4	I2	I3	I4
	6.50 ±0.73	6.31 ±0.66	6.25 ±0.46	3.98 ±0.58	5.44 ±0.51	4.88 ±0.83	3.23 ±0.61	4.17 ±0.71	3.62 ±0.74	1.60 ±0.53	2.34 ±0.48	2.13 ±0.35
p	0.914	0.826	0.674	0.002	0.009	0.033	0.037	0.042	0.001	0.147	0.090	0.416

Independent sample t-test was used for inter-group comparison, and the significance level of difference was 0.05.

Table III. Oswestry disability index (ODI) and Japanese Orthopedic Association (JOA) scores between the two fusion methods preoperatively and postoperatively

	Time point	Group P	Group I	*t*	*p*
ODI	Preoperative	36.36 ±1.46	36.53 ±1.25	0.824	0.411
	Final follow-up	8.02 ±0.76	8.01 ±0.72	0.112	0.911
JOA	Preoperative	11.49 ±0.92	11.74 ±0.94	1.791	0.075
	Final follow-up	21.56 ±0.92	21.76 ±0.74	1.603	0.111

Independent sample t-test was used for inter-group comparison, and the significance level of difference was 0.05.

For all patients, the autogenous bone taken during decompression was used for bone transplantation. The autogenous bone used for graft was obtained from the spinous process or vertebral lamina removed during the operation. This process not only avoided the complications of iliac bone extraction, but also improved the economic benefits [3].

The necessity of postoperative analgesia guidance

The operative difficulties of the posterolateral method are relatively lower than in the intervertebral method. The posterolateral method is also a common option for elderly patients who are less active and show an increased trend toward spontaneous spinal fusion [15].

Currently, there is little literature about operative injuries and their effect on postoperative pain recovery with different fusion segments and methods. The results discussed in this article show that the degree of damage from posterolateral fusion is less than from intervertebral fusion when two or three segments are operated on. In a four-segment operation, the intraoperative blood loss and blood transfusion volume of the two fusion methods are similar, but the postoperative drainage volume from the posterolateral fusion is higher than that of that of the intervertebral fusion. This suggests that the degree of tissue damage from posterolateral fusion may be more severe in a four-segment operation. The process of operation may be responsible for these findings. In the intervertebral fusion procedure, more time is spent on the removal of articular processes, on the preparation of intervertebral spaces, and on haemostasis of the venous plexus.

In the posterolateral fusion, articular processes must be retained as much as possible, so more time is spent on nerve root decompression and exposure of more surface area of the transverse processes for bone grafting. In the posterolateral fusion procedure, there can be more damage to the paravertebral muscles, and increased blood loss when dealing with articular processes or transverse processes, which increases as the number of segments increases [7]. Posterolateral fusion procedures are more likely to cause obvious paraspinal muscle injuries, leading to increased muscle atrophy or necrosis, as well as intractable postoperative lower back pain [23]. These findings are reflected in our analysis. It is necessary to explain these issues to patients and instruct them on proper postoperative analgesic treatment.

At 2 weeks and 3 months postoperatively, pain improvement was greater in patients who underwent two- or three-segment posterolateral fusion. At these same time frames, pain improvement was greater in patients who received 4-segment intervertebral fusion. This may be due to the degree of local tissue damage sustained during the operation. Although the fusion method does not determine the final operative effect [30], we can reduce the degree of tissue damage and control postoperative pain through choosing different fusion methods according to the required number of fusion segments. There is no doubt that effective pain control will increase the safety of surgery for elderly patients. The demand for pain control is often required more than functional improvement in elderly patients because their activity is generally reduced [11]. The less damage that occurs during the operation means less pain and greater satisfaction postoperatively [5]. There are many methods to control intraoperative damage, including minimizing the scope of surgery, using bilateral simultaneous dissection and fixation, using an osteotome or ultrasonic knife to remove the lamina or articular process, and using an intravenous drip of tranexamic acid. These methods can shorten the operation time and reduce the amount of blood loss, ultimately reducing the degree of damage.

Conclusions

In conclusion, both intervertebral fusion and posterolateral fusion have good therapeutic effects, and different fusion methods can be selected based on the number of fusion segments. Posterolateral fusion should be used when 3 or less levels of surgery are required. When four-level surgery is required, interbody fusion should be used.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the 3rd medical centre of Chinese PLA General Hospital. All patients signed informed consent.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Disclosure

The authors report no conflict of interest.

References

1. Chu JZ, Cui ZM. Research progress of lumbar fusion. Orthopedic J China 2012; 299: 816-818.
2. Cloward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion. Indications, operative technique, after care. J Neurosurg 1953; 10: 154-168.
3. Dreyer CH, Rasmussen M, Pedersen RH, Overgaard S, Ding M. Comparisons of efficacy between autograft and allograft on defect repair in vivo in normal and osteoporotic rats. Biomed Res Int 2020; 2020: 9358989.

4. Fenton-White HA. Trailblazing: the historical development of the posterior lumbar interbody fusion (PLIF). Spine J 2021; 21: 1528-1541.
5. He YB, Xu L, Ren LX, Liu B. Clinical analysis of complications of lumbar spinal stenosis in elderly patients with lumbar spinal stenosis. Hebei Medicine 2019; 25: 645-650.
6. Hua Y. Analysis of the curative effect of posterior open reduction and decompression with intervertebral bone graft fusion and internal fixation in the treatment of lumbar spondylolisthesis. Shandong University of Traditional Chinese Medicine, 2015.
7. Huang YH, Ou CY. Significant blood loss in lumbar fusion surgery for degenerative spine. World Neurosurg 2015; 84: 780-785.
8. Issack PS, Cunningham ME, Pumberger M, Hughes AP, Cammisa Jr FP. Degenerative lumbar spinal stenosis: evaluation and management. J Am Acad Orthop Surg 2012; 20: 527-535.
9. Ito Z, Matsuyama Y, Sakai Y, Imagama S, Wakao N, Ando K, Hirano K, Tauchi R, Muramoto A, Matsui H, Matsumoto T, Kanemura T, Yoshida G, Ishikawa Y, Ishiguro N. Bone union rate with autologous iliac bone versus local bone graft in posterior lumbar interbody fusion. Spine 2010; 35: E1101-1105.
10. Kim JY, Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, Cho YE. Minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis: comparison between isthmic and degenerative spondylolisthesis. World Neurosurg 2015; 84: 1284-1293.
11. Kong C, Lu SB, Sun XY, Wang P, Ding JZ, Guo MC, Sun XY, Guo SM. Safety and efficacy of surgical treatment for aged patients with degenerative lumbar spinal stenosis. Chinese J Spine Spinal Cord 2018; 28: 1004-1010, 1019.
12. Kunkle WA, Ameri B, Lin C, Hiratzka J. Minimally invasive approaches to the surgical treatment of lumbar stenosis. Semin Spine Surg 2019; 31: 100714.
13. Lafian AM, Torralba KD. Lumbar spinal stenosis in older adults. Rheum Dis Clin N Am 2018; 44: 501-512.
14. Lin PM. A technical modification of Cloward's posterior lumbar interbody fusion. Neurosurgery 1977; 1: 118-124.
15. Liu Z, Li HW, Wang HZ, Yu ZL, Shui Y. Research progress of lumbar fusion. Med Recapitulate 2018; 24: 2175-2180.
16. Lurie JD, Tosteson TD, Tosteson A, Abdu WA, Zhao WY, Morgan TS, Weinstein JN. Long-term outcomes of lumbar spinal stenosis: eight-year results of the Spine Patient Outcomes Research Trial (SPORT). Spine 2015; 40: 63-76.
17. Martínez CR, Lewandrowski KU, Ortíz JGR, Cuéllar GOA, León JFR. Transforaminal endoscopic discectomy combined with an interspinous process distraction system for spinal stenosis. Int J Spine Surg 2020; 14: S4-12.
18. OuYang SM. Study on the clinical effect of decompressive laminectomy and posterior lumbar interbody fusion and the life quality in the elderly patients with lumbar spinal stenosis. Pract Geriatr 2018; 9: 845-848.
19. Patel RR, Noshchenko A, Dana Carpenter R, Baldini T, Frick CP, Patel VV, Yakacki CM. Evaluation and prediction of human lumbar vertebrae endplate mechanical properties using indentation and computed tomography. J Biomech Eng 2018; 140: 1010111-1010119.
20. Ruan DK. Surgical applications and some controversy of spinal fusion in treating lumbar disease. Zgongguo Gu Shang 2015; 28: 291-293.
21. Shamji MF, Mroz T, Hsu W, Chutkan N. Management of degenerative lumbar spinal stenosis in the elderly. Neurosurgery 2015; 77 (Suppl 4): S68-74.
22. Sharma A, Brand D, Fairbank J, Ye H, Lavy C, Czernuszka J. A self-organising biomimetic collagen/nano-hydroxyapatite-glycosaminoglycan scaffold for spinal fusion. J Mater Sci 2017; 52: 12574-12592.
23. Skovrlj B, Gilligan J, Cutler HS, Qureshi SA. Minimally invasive procedures on the lumbar spine. World J Clin Cases 2015; 3: 1-9.
24. Sun F, Liang Q, Yan M, Wang H, Liu Z, Li F, Dong J, Liu T. Unilateral laminectomy by endoscopy in central lumbar canal spinal stenosis: technical note and early outcomes. Spine (Phila Pa 1976) 2020; 45: E871-E877.
25. Tsutsumimoto T, Shimogata M, Yoshimura Y, Misawa H. Union versus nonunion after postrolateral lumbar fusion: a comparison of long-term surgical outcomes in patients with degenerative lumbar spondylolisthesis. Eur Spine J 2008; 17: 1107-1112.
26. Wang JC, Mummaneni PV, Haid RW. Current treatment strategies for the painful lumbar motion segment: posterolateral fusion versus interbody fusion. Spine (Phila Pa 1976) 2005; 30 (16 Suppl): S33-43.
27. Wu W, Le AV, Mendez JJ, Chang J, Niklason LE, Steinbacher DM. Osteogenic performance of donor-matched human adipose and bone marrow mesenchymal cells under dynamic culture. Tissue Eng Part A 2015; 21 (9-10): 1621-1632.
28. Xing ZW, Wang J, Wang LG, Yang HX. Effect of systematic rehabilitation on prognosis of patients undergoing lumbar fusion and internal fixation. Chinese J Pain Med 2018; 24: 554-556.
29. Zhang G, Zhang W, Hou Y, Chen Y, Song J, Ding L. Detection of miR-29a in plasma of patients with lumbar spinal stenosis and the clinical significance. Mol Med Rep 2018; 18: 223-229.
30. Zhu D, Li WS, Chen ZQ, Qi Q, Guo ZQ, Zeng Y, Sun CG. Long-term outcome and associated factors of lumbar decompression, internal fixation and fusion for lumbar spinal stenosis. Chinese J Spine Spinal Cord 2013; 23: 865-871.