


CLINICAL ARTICLE

Benefits of Early Ambulation in Elderly Patients Undergoing Lumbar Decompression and Fusion Surgery: A Prospective Cohort Study

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Objective: To evaluate the effects of early ambulation on elderly patients' postoperative physical functional outcomes, complications, 90-day readmission rate, and the length of postoperative hospital stay.

Methods: This is a prospective cohort study conducted between June 2019 and December 2019. The study enrolled 86 elderly patients (39 males) with newly diagnosed lumbar degenerative disease undergoing single-segment decompression and fusion surgery were enrolled. Of all 86 patients, 39 voluntarily joined the early ambulation group, and 47 joined the regular ambulation group. The early ambulation group included patients ambulated within 4 h postoperatively, whereas the regular ambulation group included patients who were ambulatory at a minimum of 24 h after surgery. Participants' baseline characteristics, surgical information, ambulation ability, degree of pain, functional scores, postoperative complications, 90-day readmission rate, and length of postoperative hospital stay were recorded.

Results: Participants' baseline demographic characteristics were balanced between the early ambulation group and the regular ambulation group. The operative time and blood loss were similar between groups. The time before the first-time ambulation was 4 ± 0.5 h in the early ambulation group and 28 ± 4.5 h in the regular ambulation group. Ambulating distance was significantly longer in the early ambulation group compared with the regular ambulation group on the 1st (63 ± 45 vs 23 ± 60 m), the 2nd (224 ± 100 vs 101 ± 130 m), and the 3rd (280 ± 102.5 vs 190 ± 170 m) ambulation days based on generalized estimating equation analyses. Generalized estimating equation analyses also demonstrated that the ambulating time was longer in the early ambulation group compared with the regular ambulation group on the 1st (10 ± 5 vs 10 ± 5 min), the 2nd (19 ± 7 vs 15 ± 5 min), and the 3rd (22 ± 16.5 vs 27 ± 12 min) ambulation days. Patients in the regular ambulation group experienced a higher degree of pain than the early ambulation group patients, with an odds ratio of 1.627 ($P = 0.002$). Short-term functional independence was superior in the early ambulation group, with a lower Roland-Morris disability questionnaire score ($P = 0.008$) and Oswestry disability index ($P < 0.001$). The incidences of postoperative urinary retention (early ambulation group: 7.7%, regular ambulation group: 25.5%, $P = 0.030$) and ileus (early ambulation group: 0%, regular ambulation group: 12.8%, $P = 0.030$) were significantly higher in the regular ambulation group. The prevalence of at least one complication rate was significantly lower in the early ambulation group than in the regular ambulation group (early ambulation group, 23.1%; regular ambulation group, 46.8%, $P = 0.022$). The duration of indwelling of the drainage catheter was shorter in the early ambulation group (early ambulation group, 68 ± 24 h; regular ambulation group, 78 ± 20 h, $P = 0.001$), and the length of the postoperative hospital stay was also shorter in the early ambulation group (early ambulation group, 4 ± 0 days; regular ambulation group: 5 ± 2 days, $P < 0.001$). However, there was no statistical difference in the 90-day readmission rate between groups.

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Disclosure: The authors declare that they have no conflict of interest.

Received 15 October 2020; accepted 20 January 2021

Conclusion: Early ambulation improved patients' postoperative functional status, decreased the incidence of complications, and shortened postoperative hospital stay in elderly patients undergoing lumbar decompression and fusion surgery.

Key words: Early ambulation; Elderly patient; Nurse; Spinal surgery

Introduction

Lumbar degenerative disease (LDD) is common in aging populations. Disc degeneration, disc protrusion, and facet arthropathy are generally part of the lumbar degenerative process, and are present in nearly 90% of individuals aged over 60 years¹. LDD causes low back pain, lower limb radiation pain, and claudication. In severe cases, it may also result in cauda equina syndrome. If conservative treatments for symptomatic LDD patients do not provide good outcomes, lumbar decompression and fusion surgery may be needed. Surgery could eliminate abnormal motion between vertebrae and provide reliable posterior support, relieve pain, improve patient functionality, and maximize the health-related quality of life^{2,3}. The rate of lumbar decompression and fusion surgery among elderly patients increased from 98.3 per 100,000 people in 2004 to 170.3 per 100,000 people in 2015, a 73% increase⁴. As elderly populations have continued to grow in size, the number of patients requiring lumbar decompression and fusion surgery has increased, and was over 1.3 mn in 2019. LDD in elderly patients is becoming a social burden worldwide⁵.

Immobilization or bed rest are usually recommended after lumbar decompression and fusion surgery. However, up to 40% of patients are doubtful about or dissatisfied with the outcome after their operation⁶. There is a need to improve outcomes after surgery. Immobilization may result in delayed functional recovery, slower pain relief, and increased risk of postoperative complications. Improvements in postoperative rehabilitation may have significant value for patients. After surgery, elderly patients have a higher risk of medical complications and adverse events, such as venous thromboembolism, pressure ulcers, urinary retention, urinary tract infection, and ileus⁷⁻⁹. The reported prevalence of medical complications among elderly patients is higher than 54%⁷. Moreover, some complications are lethal. One-third of patients with postoperative venous thromboembolism develop pulmonary embolism, resulting in significant postoperative morbidity and mortality¹⁰. The high rate of medical complications in elderly patients has resulted in us changing the postoperative intervention mode from prolonged bed rest to early ambulation.

Consideration of whether to ambulate early post-surgery is a complex issue, involving both physical and psychological aspects¹¹. Ambulating early is strongly recommended in the postoperative protocols for orthopaedic surgery^{8,12}. In a retrospective study of 1504 patients who underwent total knee arthroplasty, ambulating on the first

postoperative day was associated with a shorter length of patient stay, lower hospitalization costs, and improved knee function compared with patients who began ambulating on postoperative day 2¹³. An enhanced recovery pathway designed for patients undergoing cervical spinal surgery recommended that patients start ambulating within 2 h after discharge from the post-anesthesia care unit. The result showed that early ambulation was not associated with increased complications, and there were no patient readmissions within 90 days of surgery¹⁴. The American Association of Neuroscience Nurses recommends that all orthopaedic patients mobilize quickly after spinal surgery unless complications like cerebrospinal fluid (CSF) leaks occur¹⁵. Bed rest is required for 24 to 72 h for patients with a CSF leak to avoid an increase in intradural hydrostatic CSF pressure, which may result in complications like postural headache, nausea and vomiting, nerve root herniation, and wound infection¹⁶. However, a recent randomized controlled study demonstrated that for patients with a CSF leak, there were no additional benefits of prolonged bed rest following repair of a cerebrospinal fluid leak¹⁷. Ambulation as early as possible is appropriate for all patients undergoing lumbar decompression and fusion surgery.

Compared to late ambulation following spinal surgery, early ambulation postoperatively has benefits of improving patients' physical functions, reducing post-surgery pain, lessening painkiller usage, and decreasing the rate of patients needed to be discharged to a skilled nursing facility or an acute rehabilitation facility rather than home⁷⁻⁹. Early ambulation has also been demonstrated to reduce perioperative complication rates by 20% and shorten the length of in-hospital stay by 34%⁷. Early ambulation offers a way to optimize medical management for patients undergoing spinal surgery. A study that enrolled 23,295 lumbar surgery patients with a variety of surgery types revealed that early ambulation on the postoperative day could decrease the incidence of the 90-day readmission rate by 14% and could result in savings over \$70 mn per year through prevention of readmission⁹. However, whether early ambulation reduces complications and improves physical function in elderly patients following lumbar decompression and fusion surgery remains unknown.

Early ambulation can improve the outcomes of surgery and decrease the risk of prolonged immobilization-related complications in elderly patients. The benefits of early ambulation and how early ambulation works in elderly patients in reducing immobilization-related complications after surgery should be carefully assessed. This prospective cohort study

explores early ambulation in elderly patients following lumbar decompression and fusion surgery. The purpose of the present study is: (i) to evaluate whether early ambulation improves postoperative physical outcomes; (ii) to determine whether early ambulation decreases complications and 90-day readmission rates; and (iii) to assess whether early ambulation shortens the length of postoperative hospital stay.

Materials and Methods

Inclusion and Exclusion Criteria

This was a prospective cohort study (ClinicalTrials.gov ID: NCT04133103). The inclusion criteria for enrolling patients were: (i) patients aged 60 years and older; (ii) patients with newly diagnosed LDD; (iii) patients requiring single-segment decompression and fusion surgery, and those voluntarily joining in the early ambulation group or the regular ambulation (RA) group after surgery; (iv) patients agreeing to provide access to postoperative outcomes, including an ambulation assessment, a postoperative complication assessment, and a patient-reported outcome assessment; and (v) patients agreeing to join the current prospective cohort study. The exclusion criteria were: (i) bone mineral density (BMD) $<60 \text{ mg/cm}^3$; (ii) patients with lower limb disorders; (iii) patients with severe systemic diseases; (iv) patients with coagulation disorders; (v) and patients considered unsuitable for the current trial. All surgeries were performed in our spine department between June 2019 and December 2019. The institutional review board of our institution approved this study (approval number is JST 20190924). All participants signed the consent form and received surgery from the same group of surgeons.

Patients who participated in this study were voluntarily enrolled in the early ambulation (EA) group or the RA group. The EA group was defined as patients ambulated within 4 h after surgery, whereas the RA group was patients ambulated at a minimum of 24 h postoperatively. Patients' baseline characteristic data were prospectively recorded, including age, gender, body mass index, American Society of Anesthesiologists (ASA) physical status, and the exact diagnosis of LDD. Patients' smoking status and comorbidities, including respiratory disease, cardiovascular disease, hypertension, and diabetes mellitus, were also recorded. Surgical variables were obtained, including operative time and estimated blood loss. The total amount of drainage volume, duration of indwelling of the drainage catheter, and the length of postoperative hospital stay (LOS) were also recorded.

Ambulation Assessment

Ambulation was assessed according to the distance and time that the patient ambulated on the first 3 days of ambulation. A pedometer was used to measure the step-count, and ambulating distance was equal to the step-count multiplied by the stride length of the patient. Ambulating time was measured by a registered nurse who accompanied the patient during ambulation.

Postoperative Complications

The postoperative complications included nonsurgical-related complications such as delirium, myocardial ischemia, wound infection, hematoma, and hardware failure. Immobilization-related complications, including urinary retention, urinary system infection, ileus, constipation, pneumonia, deep vein thrombosis, pulmonary embolism, and pressure ulcers, were also recorded. We reviewed the hospital medical database to identify the cause of each readmission within 90 days of discharge. An unplanned readmission was defined as patients readmitted for nonsurgical-related complications or immobilization-related complications. It is an informative marker of poor-quality care. We used it to calculate the 90-day readmission rate in the current study.

Patient-reported Outcomes

Visual Analog Scale for Low Back Pain

The visual analog scale (VAS) for low back pain is one of the most frequently used instruments for assessing the degree of pain in patients undergoing spinal surgery¹⁸. It is a self-reported scale consisting of a horizontal line (10 cm long) with anchor points of "no pain" and "worst possible pain." Patients were asked to mark on the line to describe the pain severity. The VAS score was recorded as the most severe low back pain degree that a patient suffered during the day.

Roland–Morris Disability Questionnaire

The Roland–Morris disability questionnaire (RMDQ) is a sensitive and reliable measurement for self-rating disability due to low back pain, with scores ranging from 0 (minimal disability) to 24 (severe disability)¹⁹.

Oswestry Disability Index

The Oswestry disability index (ODI) is a principal condition-specific outcome measure used to assess pain-related disability with low back pain. The ODI score system includes 10 sections and for each section of six statements the total score is 5. The score is calculated as (total score/(5 × number of questions answered)) × 100%, and a high score means a high degree of disability²⁰.

Patient-reported outcomes were collected from all enrolled patients preoperatively and postoperatively (3-day and 90-day). The VAS for low back pain was recorded every day of ambulation, and it was additionally collected before and after the first-time ambulation.

Data Analysis

All statistical analysis strategies were developed before recruiting patients. Patients' baseline sociodemographic characteristics and all outcomes were compared between two groups using independent-sample *t*-tests for normally distributed continuous variables and were presented as mean ± standard deviation. The Mann–Whitney *U*-test was used to compare continuous variables that were not normally distributed and were expressed as median (interquartile range). Fisher's exact test and the χ^2 -test were used to compare

categorical data, presented as numbers and percentages. The results, which had potential confounding effects, were also adjusted using logistic regression. Linear generalized estimating equations (GEE) were used to account for repeated measures data when assessing for statistically significant changes in two groups. In addition, 1:1 propensity score matching (PSM) analysis was performed to assess the robustness of our results. All statistical analyses were performed using SPSS statistics software, version 26.0 (IBM, Armonk, NY, USA). All tests were two-tailed, with an α of 0.05.

Results

A total of 151 consecutive elderly patients were assessed for eligibility. Finally, 86 patients were enrolled in the current study (Fig. 1). Of the 86 participants, 39 voluntarily joined the EA group, and 47 joined the RA group. Patients' baseline demographic characteristics were balanced between groups. The ASA physical status and the exact diagnosis of LDD were also similar between groups. There was no significant difference in the prevalence of comorbidities (Table 1).

The operative time and blood loss were similar between groups. The total amount of drainage volume

(EA group: 500 ± 160 mL, RA group: 540 ± 110 mL, $P = 0.677$) was not significantly different between groups. However, the duration of indwelling of the drainage catheter was shorter in the EA group (EA group: 68 ± 24 h, RA group: 78 ± 20 h, $P = 0.001$). The length of postoperative hospital stay was also shorter in the EA group compared with the RA group (EA group: 4 ± 0 days, RA group: 5 ± 2 days, $P < 0.001$) (Table 2).

Postoperative Complications

The incidences of postoperative urinary retention (EA group: 7.7%, RA group: 25.5%, $P = 0.030$) and ileus (EA group: 0%, RA group: 12.8%, $P = 0.030$) were significantly higher in the RA group. However, the incidence of delirium (EA group: 2.6%, RA group: 2.1%, $P = 1.000$), constipation (EA group: 12.8%, RA group: 27.7%, $P = 0.092$), hematoma (EA group: 2.6%, RA group: 4.3%, $P = 1.000$), and wound infection (EA group: 2.6%, RA group: 4.3%, $P = 1.000$) showed no significant differences between groups. The rate of developing at least one complication (EA group: 23.1%, RA group: 46.8%, $P = 0.022$) was higher in the RA group. No patient in either group had hardware failure, myocardial ischemia, urinary system

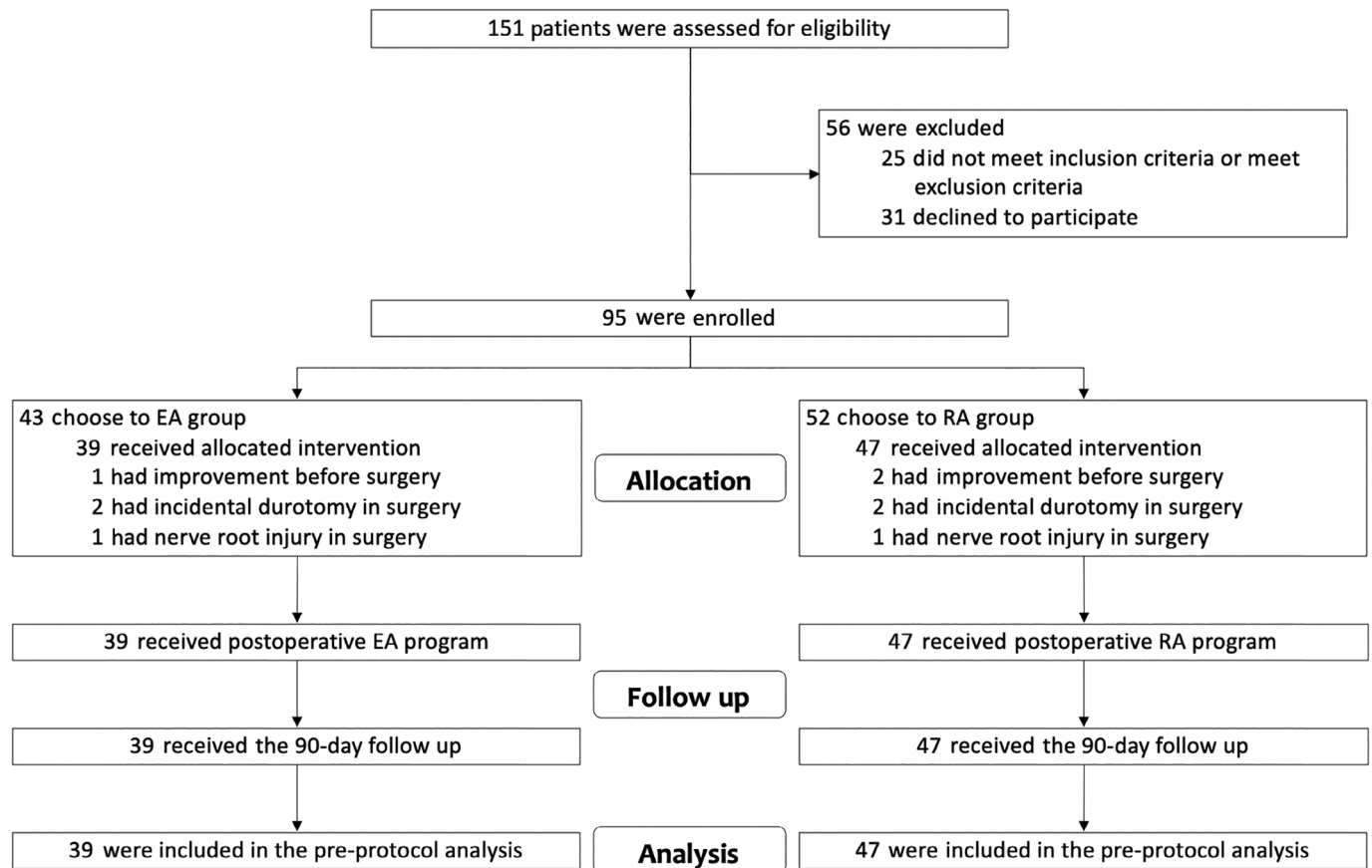


Fig. 1 Flow diagram illustrating the patient inclusion process.

TABLE 1 Demographic characteristics of patients

Characteristics	EA group (n = 39)	RA group (n = 47)	P-value
Age (years)	61 (11)	63 (7)	0.503*
Male sex (cases, %)	15 (38.50)	24 (51.10)	0.243 [†]
Body mass index (kg/m ²)	25.39 (4.11)	24.17 (3.51)	0.142*
Smoker (cases, %)	12 (30.80)	14 (29.80)	0.921 [†]
Respiratory disease (cases, %)	0 (0)	3 (6.40)	0.248 [‡]
Cardiovascular disease (cases, %)	8 (20.50)	5 (10.60)	0.203 [†]
Hypertension (cases, %)	8 (20.50)	14 (29.80)	0.326 [†]
Diabetes mellitus (cases, %)	3 (7.70)	4 (8.50)	1.000 [‡]
ASA physical status (cases, %)			0.381 [†]
ASA I	13 (33.30)	20 (42.60)	
ASA II	26 (66.70)	27 (57.40)	
Diagnosis (cases, %)			0.848 [†]
Lumbar disc herniation	12 (30.80)	16 (34.00)	
Lumbar spinal stenosis	8 (20.50)	11 (23.40)	
Lumbar spondylolisthesis	19 (48.70)	20 (42.60)	

* The values are determined using the Mann-Whitney *U*-test.
[†] The values are determined using the χ^2 -test.
[‡] The values are determined using Fisher's exact test.
 ASA, American Society of Anesthesiologists.

infection, pneumonia, deep vein thrombosis, pulmonary embolism, or pressure ulcers. The 90-day readmission rate between groups was not statistically different. One patient in the EA group was readmitted 11 days post-surgery for incision site infection (Table 3).

Ambulation Assessment

The time before the first-time ambulation was 4 ± 0.5 h in the EA group and 28 ± 4.5 h in the RA group. As shown in Table 4, RA was associated with less ambulation distance for the first three ambulation days (odds ratio [OR] 1.499E-28, 95% confidence interval [CI] 7.328E-37 to 3.065E-20, $P < 0.001$, adjusted for demographic characteristics, operative time, and blood loss). The total ambulation distance in the first 3 days of ambulation was also better in the EA group (EA group: 539.5 ± 192.5 m, RA group: 294 ± 380 m, $P = 0.002$). For the ambulation time, the RA was associated with less ambulation time (OR 0.009, 95% CI 0.001 to 0.062, $P < 0.001$, adjusted for demographic characteristics, operative time, and blood loss); however, the total ambulation time in the first 3 days of ambulation showed no statistical difference (EA group: 52.75 ± 19.75 min, RA group: 50 ± 20 min, $P = 0.093$).

Patient-reported Outcomes

Early ambulation after surgery was also associated with better functional recovery as compared with RA. The estimate odds ratio for the association between RA and the risk of higher RMDQ score was 6.254 (95% CI 1.601 to 24.427,

TABLE 2 Surgical information analysis between groups

Variables	EA group (n = 39)	RA group (n = 47)	P-value*
Operative time (min)	90 (35)	120 (30)	0.318
Blood loss (mL)	200 (90)	200 (90)	0.460
Total amount of drainage volume (mL)	500 (160)	540 (110)	0.677
Duration of indwelling of the drainage catheter (h)	68 (24)	78 (20)	0.001
Length of postoperative hospital stay (days)	4 (0)	5 (2)	<0.001

* The values are determined using the Mann-Whitney *U*-test.; EA, early ambulation; RA, regular ambulation.

$P = 0.008$, adjusted for demographic characteristics, operative time, and blood loss), and the association between RA and the risk of higher ODI score was 352.220 (95% CI 20.382 to 6086.554, $P < 0.001$, adjusted for demographic characteristics, operative time, and blood loss). Patients in the RA group also experienced a higher degree of pain compared with the EA group patients, with an odds ratio of 1.627 (95% CI 1.204 to 2.200, $P = 0.002$, adjusted for demographic characteristics, operative time, and blood loss pain) (Table 4).

Overall, the results of 1:1 PSM analysis were consistent with the above multivariate analysis results (supplementary material).

TABLE 3 Complication information analysis between groups (cases, %)

Variables	EA group (n = 39)	RA group (n = 47)	P-value
Urinary retention	3 (7.70)	12 (25.50)	0.030*
Delirium	1 (2.60)	1 (2.10)	1.000 [†]
Ileus	0 (0)	6 (12.80)	0.030 [†]
Constipation	5 (12.80)	13 (27.70)	0.092*
Hematoma	1 (2.60)	2 (4.30)	1.000 [†]
Wound infection	1 (2.60)	2 (4.30)	1.000 [†]
90-day readmission	1 (2.60)	0 (0)	0.453 [‡]
At least one complication	9 (23.10)	22 (46.80)	0.022*
At least one complication	9 (23.10)	22 (46.80)	0.009 [‡]

* The values are determined using the χ^2 -test; [†] The values are determined using Fisher's exact test.

[‡] Binary logistic regression was used to assess the relationship between at least one complication and the regular ambulation group; the reference is the early ambulation group. The regression covariates are demographic characteristics, including age, gender, body mass index, coexisting conditions (i.e. smoker, respiratory disease, cardiovascular disease, hypertension, and diabetes mellitus), ASA physical status and diagnosis, and surgical information (including operative time and blood loss). $P = 0.009$ ($\beta = 2.568$; Wald = 6.892; 95% CI: 1.917 to 88.670).

ASA, American Society of Anesthesiologists; EA, early ambulation; RA, regular ambulation.

TABLE 4 Ambulation and patient report outcomes analysis using linear generalized estimating equations, mean (SD)

Variables	EA group (n = 39)	RA group (n = 47)	OR	95% CI		P-value*
				Lower	Upper	
Ambulation distance (m)			1.499E-28	7.328E-37	3.065E-20	<0.001
The 1st ambulation day	63 (45)	23 (60)				
The 2nd ambulation day	224 (100)	101 (130)				
The 3rd ambulation day	280 (102.5)	190 (170)				
Ambulation time (min)			0.009	0.001	0.062	<0.001
The 1st ambulation day	10 (5)	10 (5)				
The 2nd ambulation day	19 (7)	15 (5)				
The 3rd ambulation day	22 (16.5)	27 (12)				
RMDQ			6.254	1.601	24.427	0.008
Preoperation	10 (6)	8 (13)				
The 3rd ambulation day	8 (4)	9 (5)				
The 90-day follow-up	2 (1)	4 (2)				
ODI ratio			352.220	20.382	6086.554	<0.001
Preoperation	49 (20)	49 (40)				
The 3rd ambulation day	38 (17)	40 (13)				
The 90-day follow-up	27 (13)	31 (18)				
VAS			1.627	1.204	2.200	0.002
Pre-first-time ambulation	3 (2)	3 (1)				
Post-first-time ambulation	3 (1)	4 (2)				
The 2nd ambulation day	2 (1)	3 (1)				
The 3rd ambulation day	2 (2)	2 (1)				
The 90-day follow-up	1 (0)	1 (1)				

*For ambulation distance and ambulation time, the data on the 1st day, the 2nd day, and the 3rd day assessments were used for regression analysis. For RMDQ and ODI, the data on pre-ambulation, the 3rd day of ambulation, and the 90-day follow-up assessments were used for regression analysis. For VAS, the data on pre-ambulation, post-ambulation, the 2nd day of ambulation, the 3rd day of ambulation, and the 90-day follow-up assessments were used for GEE regression analysis. For all variables, the reference is the EA group. Factors included in the GEE model were demographic characteristics, including age, gender, body mass index, coexisting conditions (smoker, respiratory disease, cardiovascular disease, hypertension, and diabetes mellitus), ASA physical status and diagnosis, and surgical information (including operative time and blood loss).; ASA, American Society of Anesthesiologists; CI, confidence interval; EA, early ambulation; GEE, generalized estimating equations; ODI, Oswestry disability index; OR, odds ratio; RA, regular ambulation; RMDQ, Roland-Morris disability questionnaire; VAS, visual analog scale.

Discussion

Prolonged immobilization induced a high risk of complications and mortality in post-surgery patients, prompting us to explore approaches to better manage patients postoperatively. Adogwa *et al.* demonstrated that early ambulation could reduce the perioperative complication rate by 20%⁷. In a prospective cohort study, Siu *et al.* also demonstrated that early ambulation after hip fracture surgery for 1.8 days decreased the mortality rate from 7.3% to 5.3%²¹. However, few studies have focused on the effects of early ambulation post-surgery for elderly patients. This current prospective cohort study identified that early ambulation in elderly patients after lumbar decompression and fusion surgery improved functional status, decreased the incidence of complications, and shortened the length of postoperative hospital stay.

Early Ambulation Decrease Postoperative Pain Level

Patient refusal to ambulate after surgery was usually due to concern about experiencing pain after movement²². However, our current study showed that ambulation does not increase the degree of pain; indeed, early ambulation contributed to reducing the postoperative pain level. In

contrast to the late ambulators, this benefit continued up to the 90-day follow up. Research conducted by Brusko *et al.* was consistent with this result, which demonstrated that the degree of pain was 30% lower in the early ambulation group on the first day postoperatively compared with the control group⁸. Early ambulation has also been demonstrated to reduce the postoperative daily pain scores in scoliosis patients²³. Another study that focused on patients undergoing total knee arthroplasty also showed that early rehabilitation within 24 h decreased the postoperative pain level²⁴.

Early Ambulation Facilitates the Functional Recovery Process

Although conquering the fear of pain may be necessary, participating in early postoperative ambulation helps to reduce the postoperative pain level and facilitates the functional recovery process by avoiding skeletal muscle disuse atrophy, improving body fluid retention, and preventing immune system malfunction²². Early ambulators demonstrated superior mobility ability, with longer ambulating distances and more ambulating time than the late ambulators in the RA group. These results were similar to those in Brusko *et al.* and

Adogwa *et al.*, who also demonstrated that early ambulators have better daily mobility ability and greater ambulating time compared to late ambulators^{7,8}.

In the current study, patients in both groups showed better RMDQ and ODI scores at 90-day follow up compared with preoperation, indicating that they had all experienced physical function recovery post-surgery. However, patients in the EA group had significantly better physical function outcomes than those in the RA group. McGregor *et al.* also demonstrated the advantage of early ambulation for functional recovery, which showed that active ambulation was more effective than prolonged ambulation in improving both short-term and long-term functional status after surgery. Similar results were found in other studies demonstrating that functional independence was superior in early ambulators; most of these patients were discharged directly to home rather than to a rehabilitation center^{7,9}. For elderly patients, improved pain and physical function outcomes in the early postoperative stage are relevant to patients' overall well-being and are important for decreasing postoperative complications.

Early Ambulation Decreases Immobilization-Related Complications

Immobilization after surgery may cause degeneration in various organ systems, and results in severe complications. Some complications may eventually lead to deadly diseases, such as pulmonary embolism resulting from deep vein thrombosis and sepsis from pressure ulcers. Postoperative ambulation is a significant predictor of patients not developing complications²⁶. In the current study, early ambulation showed favorable results, with patients in the EA group having 69.8% lower incidence of urinary retention, and no patients had ileus. These findings were also demonstrated in another study, which showed that early ambulation was associated with decreased incidence of urinary retention and ileus⁹. Moreover, early ambulation contributed to a 50.6% lower probability of developing at least one complication than regular ambulation. Although one patient in the EA group was readmitted for incision site infection, this was not related to postoperative ambulation. In fact, in a study by Park *et al.*, early ambulation was associated with a 19% lower 90-day readmission rate²⁷.

Early Ambulation Shortens the Length of Postoperative Hospital Stay

Early ambulation enables rapid removal of drainage catheters, which shortens the time for bacterial migration from the external to the internal environment and decreases infection and inflammation postoperation²⁸. In our study, early ambulators had a shorter LOS after the operation compared with the late ambulators. Similarly, the LOS was 35% shorter in the early ambulation cohort in an ambispective cohort review⁷. Zakaria *et al.* also

demonstrated that postoperative ambulation on the day of surgery was associated with a shorter LOS⁹. Shortening the LOS has great economic significance for healthcare and societal costs. A study involving adolescent patients undergoing idiopathic scoliosis surgery showed that a 1-day shorter LOS led to an approximately US\$2000 reduction in total patient costs²⁹. Another study examining patients after total knee arthroplasty found that in an early discharge group, a decrease in LOS of 22 h resulted in financial savings of approximately US\$600³⁰.

Limitations

We acknowledge that there were several limitations in our study. First, this was a prospective cohort study. Although the logistic regression analysis, generalized estimating equations analysis, and propensity score matching were used to adjust potential confounding factors, a randomized controlled trial is still required to verify the relationship between early ambulation and decreased postoperative adverse events and better functional recovery. In addition, the current study was a single-center study. A prospective multicentric randomized controlled study with larger cohorts and long-term follow up in future will be critical to fully understand the long-term benefits of an early ambulation protocol after spinal surgery and hospitals' direct healthcare costs associated with early ambulation.

Conclusion

In our experience, early ambulation in elderly patients undergoing lumbar decompression and fusion surgery is associated with improving functional status, decreasing incidence of complications, and shortening of the length of postoperative hospital stay. It is also necessary to conduct future randomized controlled trials to reduce potential bias and to verify the outcomes.

Acknowledgment

This study was supported by Beijing Municipal Health Commission (BMHC2018-4).

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Table 1. Demographic characteristics of patients after propensity score matching.

Table 2. Surgical information analysis between groups after propensity score matching.

Table 3. Complication information analysis between groups after propensity score matching.

Table 4. Ambulation and patient-reported outcomes analysis using linear generalized estimating equations after propensity score matching.

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