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Advancing the timing of drainage removal: a comprehensive analysis of different drainage removal criteria in patients undergoing short-level lumbar fusion surgery

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Abstract

Objective To specifically evaluate the safety and benefit of different drainage removal criteria (50 ml and 100 ml per 24 h) in patients undergoing short-level lumbar fusion surgery.

Methods Patients with degenerative lumbar diseases who underwent short level lumbar fusion with instrumentation between January 2021 and January 2023 were retrospectively recruited in the study. Based on the different criteria for drainage removal, the patients were divided into 2 groups (group A and group B). To control for confounding factors, a 1:1 nearest propensity score matching of significant variation, especially age, gender, BMI, number of fused levels, intraoperative blood loss, and surgical duration, were performed between groups. Perioperative outcomes were compared between groups. Multivariate logistic regression was performed to determine the risk factors for overall complications.

Results A total of 1004 eligible patients were reviewed in this study with 676 patients in group A and 328 patients in group B. After propensity score matching, 616 patients, 308 in each group were included in the final analysis. There were significantly more patients getting drainage removed on POD 2 (23.1% vs. 32.1%, $p=0.012$) and POD 3 (37.0% vs., 45.1%, $p=0.041$) in group B. In addition, patients in group B had earlier postoperative timing of ambulation (3.87 ± 1.12 vs. 2.41 ± 1.34, $p=0.012$). No significant difference in symptomatic hematoma and surgical site infection was observed, but there were significant fewer overall complications (10.39% vs. 5.19%, $p=0.016$) in the group B. Multivariate logistic regression indicated that postoperative timing of ambulation (OR 2.38, 95% CI 1.19–3.97, $p<0.001$) was independently associated with overall complications.

Conclusion In this study, we found that the relaxation of the criteria for drainage removal could significantly shorten the length of stay, in addition, it could promote early postoperative ambulation of patients and thus reduce the occurrence of perioperative overall complications.

Keywords Drainage removal, Ambulation, lumbar fusion surgery, hematoma, surgical site infection

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Introduction

The world's population is aging. By 2050, 1 in 6 people in the world is expected to be over the age of 65 [1]. With the increasing elderly population, degenerative lumbar spine conditions have become more prevalent [2–4], affecting nearly 270 million people worldwide [5]. Lumbar fusion surgery usually requires the drainage usage within the incision to facilitate the drainage of postoperative blood and fluid, thereby avoiding complications such as surgical site infection and worsening of neurological function due to the formation of hematoma [6, 7].

However, in recent years, increasing studies have shown that there is no significant difference in the incidence of hematoma and wound infection between patients with and without drainage usage [8, 9]. Furthermore, with the prevalence of enhanced recovery after surgery protocol (ERAS) in the field of spinal surgery, the early removal or no-drainage has been gaining attention, as the primary aim of ERAS is to reduce the length of hospital stay and the drainage usage significantly prolongs the length of hospital stay [10]. However, despite evidence that no-drainage usage is safe and may even be associated with lower complications, only few patients are managed without drainage, which indicates that the majority of surgeons still tend to place drainage after surgery.

In this context, the importance of early removal of drainage is self-evident. Generally, the criteria for drainage removal is primarily determined by the volume of drainage, but there is no consensus on this protocol [11]. Some doctors remove the drainage on the second day regardless of the blood volume; some have variable drainage removal criteria (less than 50 or 100 ml per 24 h). However, the standard of 50 ml seems to be strict, and a more lenient criterion (such as 100 ml per 24 h) would be more conducive to the early drainage removal. Therefore, the primary objective of this study is to evaluate the safety and benefits of different drainage removal criteria (50 ml and 100 ml per 24 h) in patients undergoing short-level lumbar fusion surgery.

Methods

Study design and population

This study was a retrospective, single-center study. The study was performed in compliance with ethical standards and was approved by the ethical review committee of Xuanwu Hospital, Capital Medical University (IRB#20180186). All patients in this study obtained informed consent before surgery. Patients with degenerative lumbar diseases who underwent lumbar fusion with instrumentation (posterior lumbar interbody fusion, PLIF or transforaminal lumbar interbody fusion, TLIF) involving 1 or 2 segments by 5 experienced spine specialists between January 2021 and January 2023 were recruited in the study. Patients with a history of spine surgery, minimally invasive surgery, intraoperative bleeding over 2500 ml, coagulopathies, dural tears or incomplete medical record information were excluded. Wound drainage was placed in all procedures before the incision was closed in this study. Based on the different criteria for drainage removal, the patients were divided into 2 groups (group A and group B). The drainage was discontinued according to the volume of drainage output with less than 50 ml per 24 h for patients in group A by 3 of 5 spine specialists and with less than 100 ml per 24 h for patients in group B by the other 2 spine specialists.

Treatment protocol

All patients were placed in the prone position under general anesthesia. The surgical techniques employed in groups were comparable, including conventional midline access with unilateral or bilateral decompression, followed by PLIF or TLIF combined with pedicle screw and rod fixation. After ensuring sufficient decompression and meticulous hemostasis of the nerve roots and spinal cord, 1 or 2 silicone/closed suction drains were inserted into the subfascial space, followed by closure of the incision. The decision to utilize a single drain for cases with spinous process removal or two drains for cases with preserved spinous processes (one on each side) was made. Closure of the incisions involved sequential suturing of the muscle, fascia, and skin layers. Additionally, a standardized enhanced recovery after surgery protocol, as previously described by our department [12], was implemented throughout the perioperative management.

Data collection

All data were extracted from the electronic medical record system. Preoperative baseline data were recorded including demographic characteristics [age, gender, body mass index (BMI)]; medical history (hypertension, diabetes, smoking, drinking, osteoporosis); and laboratory tests [red blood cell count (RBC), hemoglobin, international normalized ratio (INR)]. Surgical-related variables included diagnosis, type of surgery, surgical duration, number of fused levels, intraoperative blood loss, number of intraoperative autologous or allogeneic blood transfusion, number of postoperative blood transfusion. Regarding the indication of blood transfusion, the conditions of all patients were monitored intraoperatively by an anesthesiologist who decided whether to transfuse. After surgery, blood transfusion was administered if the hemoglobin level was <8 g/dL or for symptomatic patients with hemoglobin between 8 and 10 g/dL. Outcome measures included postoperative complications, especially postoperative hematoma and surgical site infection, major complications, postoperative total drainage output per patient and daily drainage, postoperative

timing of ambulation (defined as the number of hours until a patient moved out of bed beyond a chair according to previously published by our department [13]), postoperative length of stay (LOS) and prolonged LOS, defined as an inpatient hospital stay longer than the 75th percentile of LOS. To simplify data analysis, a comprehensive complication index, calculated and weighted based on the Clavien-Dindo classifcation, was used to summarize all postoperative complications and their severity. Major complications were determined if comprehensive complication index scores were >20, equivalent to the single score of Clavien-Dindo classifcation II.

Table 1 Demographic data, medical history, laboradory data, and surgical-related data before propensity score matching

Variables	Group A	Group B	*p*-value
	N=676	*N*=328	
Demographic data			
Age	73.09±5.84	71.99±5.52	0.004
Gender			0.492
Female	401 (59.3%)	202 (61.6%)	
Male	275 (40.7%)	126 (38.4%)	
BMI	25.72±3.68	25.06±3.62	0.008
Medical history			
Hypertension	417 (61.7%)	212 (64.6%)	0.365
Diabetes	203 (30.0%)	103 (31.4%)	0.658
Smoking	91 (13.5%)	37 (11.3%)	0.331
Drinking	54 (8.0%)	26 (7.9%)	0.973
Osteoporosis	96 (14.2%)	37 (11.3%)	0.2
Laboratory data			
RBC	4.26±0.49	4.24±0.52	0.556
Hemoglobin	130.47±14.02	129.79±15.12	0.487
INR	0.97±0.09	0.97±0.08	0.326
Surgical-related data			
Diagnosis			0.434
Lumbar stenosis	384 (56.8%)	177 (54.0%)	
Spondylolisthesis	69 (10.2%)	42 (12.8%)	
Herniated disc	233 (33.0%)	109 (33.2%)	
Type of surgery			0.492
PLIF	278 (41.1%)	128 (39.0%)	
TLIF	281 (41.6%)	149 (45.4%)	
Combined	117 (17.3%)	51 (15.6%)	
Number of fused levels			
1	218 (32.2%)	201 (61.3%)	<0.001
2	458 (67.8%)	127 (38.7%)	
Drainage number			0.186
Single	283(41.9%)	123(37.5%)	
Double	393(58.1%)	205(62.5%)	
Intraoperative blood loss	316.06±280.77	207.96±180.28	<0.001
Surgical duration	204.46±58.79	181.47±54.87	<0.001
Number of intraoperative transfusion			0.896
Autologous	87 (12.9%)	57 (17.4%)	
Allogeneic	13 (1.9%)	8 (2.4%)	
Number of postoperative transfusion	41 (6.1%)	27 (8.2%)	0.2

BMI: body mass index; RBC: red blood cell; INR: international normalized ratio; PLIF: posterior lumbar interbody fusion; TLIF: transforaminal lumbar interbody fusion

Statistical analysis

Categorical variables were expressed as frequencies and percentages. Histograms and Shapiro-Wilk test were used to evaluate the distribution of numerical variables. Continuous variables were represented by mean and standard deviation (SD) if normally distributed; otherwise, median and interquartile (IQR) were used. To control for confounding factors, a 1:1 nearest propensity score matching of significant variation, especially age, gender, BMI, number of fused levels, intraoperative blood loss, and surgical duration, were performed between groups with match tolerance was set as 0.02. After propensity score matching, continuous variables with a normal distribution were analyzed using Student's t test, if not, Wilcoxon rank sum test was performed. Categorical variables were analyzed using chi-square or Fisher's exact tests. Multivariate logistic regression was performed to determine the potential risk factors for overall complications. All analyses were performed using SPSS software version 25.0 (SPSS, Inc., Armonk, NY, USA), and *P*-values<0.05 were considered statistically significant.

Results

A total of 1004 eligible patients were reviewed in this study with 676 patients in group A and 328 patients in group B. There was significant difference in age (73.09±5.84 vs. 71.99±5.52, $p=0.004$) and BMI (25.72±3.68 vs. 25.06±3.62, $p=0.008$) between groups. There were more patients with 2 fused levels (67.8% vs. 38.7%, $p<0.01$), intraoperative blood loss (316.06±280.77 vs. 207.96±180.28, $p<0.001$), and longer surgical duration (204.46±58.79 vs. 181.47±54.87, $p<0.001$) in group A. There was no significant difference in other variables between groups. The detailed characteristics were summarized in Table 1. After propensity score matching, 616 patients, 308 in each group were included in the final analysis. There were more patients with smoking (11.4% vs. 16.9%, $p=0.049$) and more patients with higher INR (0.96±0.07 vs. 0.97±0.08, $p=0.049$) in group B (Table 2).

Perioperative outcomes were shown in Table 3. Although the postoperative total drainage volume was comparable between groups, more patients met the criteria for drainage removal on POD 2 (23.1% vs. 32.1%, $p=0.012$) and POD 3 (37.0% vs., 45.1%, $p=0.041$) in group B (Fig. 1). Although fewer patients suffering from symptomatic hematoma and surgical site infection in group B, there was no significant difference. It is worth noting that there was one patient undergoing reoperation for symptomatic hematoma in group A (Table 4).

Table 2 Demographic data, medical history, laboratory data, and surgical-related data after propensity score matching

Variables	Group A	Group B	*p*-value
	N = 308	*N* = 308	
Demographic data			
Age	72.38 ± 5.93	72.21 ± 5.57	0.716
Gender			0.285
Female	192 (62.3%)	179 (58.1%)	
Male	116 (37.7%)	129 (41.9%)	
BMI	25.05 ± 3.82	25.20 ± 3.64	0.609
Medical history			
Hypertension	201 (65.3%)	195 (63.3%)	0.614
Diabetes	97 (31.5%)	91 (29.5%)	0.6
Smoking	35 (11.4%)	52 (16.9%)	0.049
Drinking	25 (8.1%)	30 (9.7%)	0.48
Osteoporosis	37 (12.0%)	40 (13.0%)	0.715
Laboratory data			
RBC	4.28 ± 0.50	4.25 ± 0.52	0.962
Hemoglobin	129.92 ± 14.21	129.94 ± 15.27	0.987
INR	0.96 ± 0.07	0.97 ± 0.08	0.049
Surgical-related data			
Diagnosis			0.589
Lumbar stenosis	134 (43.5%)	141 (45.8%)	
Spondylolisthesis	34 (11.0%)	39 (12.7%)	
Herniated disc	140 (45.5%)	128 (41.5%)	
Type of surgery			0.601
PLIF	113 (36.7%)	125 (40.6%)	
TLIF	157 (51.0%)	146 (47.4%)	
Combined	38 (12.3%)	37 (12.0%)	
Number of fused levels			0.416
1	180 (58.4%)	170 (55.2%)	
2	128 (41.6%)	138 (44.8%)	
Drainage number			0.214
Single	126(40.9%)	111(36.0%)	
Double	182(59.1%)	197(64.0%)	
Intraoperative blood loss	305.44 ± 151.21	214.58 ± 183.71	0.5
Surgical duration	183.74 ± 48.66	183.92 ± 54.58	0.966
Number of intraoperative transfusion			0.922
Autologous	61 (19.8%)	50 (16.2%)	
Allogeneic	9 (2.9%)	7 (2.2%)	
Number of postoperative transfusion	34 (11.0%)	24 (7.8%)	0.168

BMI: body mass index; RBC: red blood cell; INR: international normalized ratio; PLIF: posterior lumbar interbody fusion; TLIF: transforaminal lumbar interbody fusion

There was no significant difference in other perioperative complications between groups. However, there were significant fewer overall complications (10.39% vs. 5.19%, $p=0.016$) in the group B. In addition, patients in group B had shorter postoperative LOS (6.1 vs. 4.8, $p<0.001$) and smaller proportion of prolonged LOS (37.99% vs. 22.08%, $p<0.001$). Regarding the postoperative timing of ambulation, the average postoperative timing of ambulation in group B was shorter than group A (3.87±1.12 vs. 2.41±1.34, $p=0.012$). Further analysis indicated that more patients ambulate in POD 2 (46.8% vs. 63.9%, $p<0.001$) in the group B (Fig. 2).

Table 3 Perioperative outcomes between groups

Outcome measure	Group A	Group B	*p*-value
	N = 308	*N* = 308	
Postoperative total drainage volume	370.14 ± 78.44	361.47 ± 81.73	0.217
RBC count (POD 1) ($\times 10^{12}$/L)	3.87 ± 0.51	3.81 ± 0.54	0.627
RBC count (last time)($\times 10^{12}$/L)	3.77 ± 0.57	3.80 ± 0.63	0.798
Hemoglobin (POD 1) (g/L)	118.35 ± 17.42	116.87 ± 16.54	0.415
Hemoglobin (last time) (g/L)	114.68 ± 15.68	113.58 ± 16.32	0.714
Perioperative complications			
Urinary retention	5 (1.62%)	3 (0.97%)	0.722
Deep vein thrombosis	3 (0.97%)	1 (0.32%)	0.616
Urinary infection	5 (1.62%)	2 (0.65%)	0.447
Acute cerebral infarction	1 (0.32%)	0 (0%)	1
Pneumonia	3 (0.97%)	1 (0.32%)	0.616
Delirium	6 (1.95%)	2 (0.65%)	0.286
Heart failure	0 (0%)	1 (0.32%)	1
Myocardial infarction	1 (0.32%)	3 (0.97%)	0.616
Symptomatic hematoma	3 (0.978%)	1 (0.32%)	0.616
Surgical site infection	5 (1.62%)	2 (0.65%)	0.447
Overall complications	32 (10.39%)	16 (5.19%)	0.016
Major complications	14 (4.54%)	9 (2.92%)	0.288
Postoperative timing of ambulation	3.87 ± 1.12	2.41 ± 1.34	0.012
Postoperative LOS	6 (5,9)	5 (4,8)	< 0.001
Prolonged LOS	117 (37.99%)	68 (22.08%)	< 0.001
Reoperation	1 (0.32%)	0 (0%)	1

RBC: red blood cell; POD: postoperaive day; LOS: length of stay

After adjusting for all variables with *p*-value<0.10 in the univariate analysis (age, female, BMI, smoking, intraoperative blood loss, surgical duration, number of fused levels, postoperative total drainage volume, and postoperative timing of ambulation), the result of multivariate logistic regression indicated that postoperative timing of ambulation (odd ratio OR 2.38, 95%CI 1.19–3.97, $p<0.001$) was independently associated with overall complications (Table 5).

Discussion

Surgical site infection and hematoma in spine surgery leading devastating morbidity to the patient [9]. Due to the large size of surgical area and resultant more internal bleeding, surgeons are more inclined to use drainage to avoid reoperation for symptomatic hematoma and hazardous surgical site infection [11]. However, despite drainage being widely used in spine surgery, its benefits remain contentious [6, 8, 14, 15]. Mirzai et al. conducted an RCT of 50 patients (22 patients in with drainage and

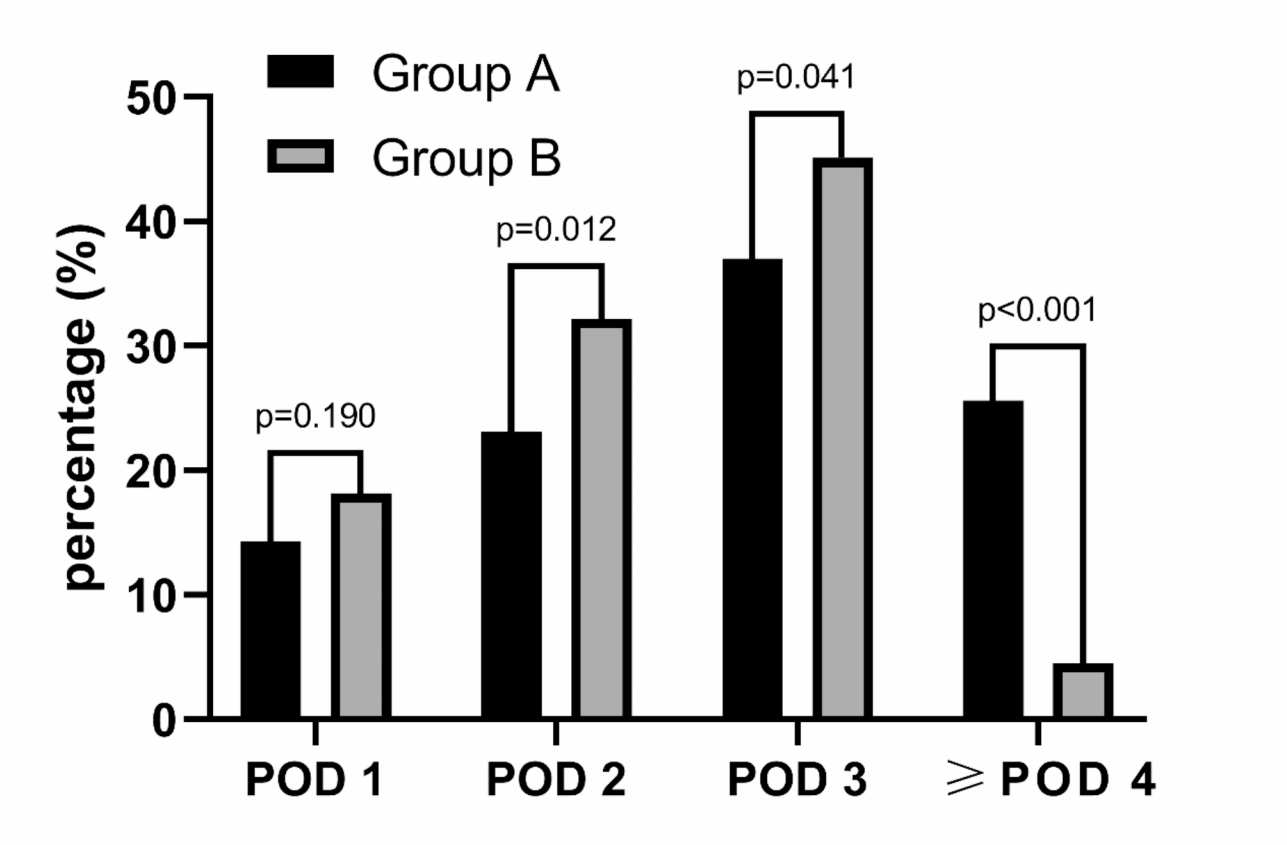

Fig. 1 The detailed characteristics of drainage removal according to respective criteria

Table 4 Detailed of patients who developed a hematoma

	Group A			Group B
	Patient 1	**Patient 2**	**Patient 3**	**Patient 4**
Age	74	68	71	63
Gender	Female	Male	Female	Male
Levels operated	L4-L5	L3-L5	L4-L5	L3-L4
Surgical duration	154	201	167	149
Postoperative timing of ambulation	POD 2 POD 1	POD 2 POD 2	POD 5 POD 2	POD 3 POD 1
Timing of drainage removal	15	10	13	11
Postoperative LOS	Neurological deficit	Intractable pain	Neurological deficit	Intractable pain
Clinical signs	POD 4	POD 2	POD 2	POD 3
Time of hematoma occurrence	Yes	No	No	No
Reoperation	No	No sequelae	No sequelae	No sequelae
Neurological recovery when discharged				

LOS: length of stay; POD: postoperative day

28 patients without drainage) undergoing lumbar disc herniation surgery. They reported that the incidence of epidural hematoma on the POD 1 in patients with drainage and without drainage was 36% and 89%, respectively ($p=0.000$). Therefore, the authors pointed that the occurrence of postoperative epidural hematoma was still common in lumbar discectomy even after careful hemostasis, which necessitated the drainage usage [14]. In contrast, in a multicenter randomized prospective controlled clinical trial of 93 patients (45 patients in drainage group and 48 patients in non-drainage group), Molina et al. indicated that patients in non-drainage group presented shorter LOS and better outcomes, with similar complication rates. Therefore, they summarized that postoperative drainage was not recommended in patients undergoing posterior spinal decompression and fusion up to three levels for degenerative lumbar conditions [8]. In addition, numerous Mata-analysis indicated that routine use of drainage in lumbar spinal surgery did not reduce the risk of surgical site infection and their absence did not increase the risk of hematoma formation [9, 16].

It seems that the drainage usage after lumbar fusion surgery appears not to be necessary. However, this measure has not been adopted and implemented by the majority of surgeons, alternatively, even though practitioners agree that these surgeries present a very low hemorrhagic risk, the fear of postoperative hematoma, with the irretrievable sequelae of neurological deficit, haunts the mind of the very few cases [17]. In addition, the current best evidence that supported non-drainage usage was presented with its limitations, among which, the sample size was the most hotly debated. Existing studies

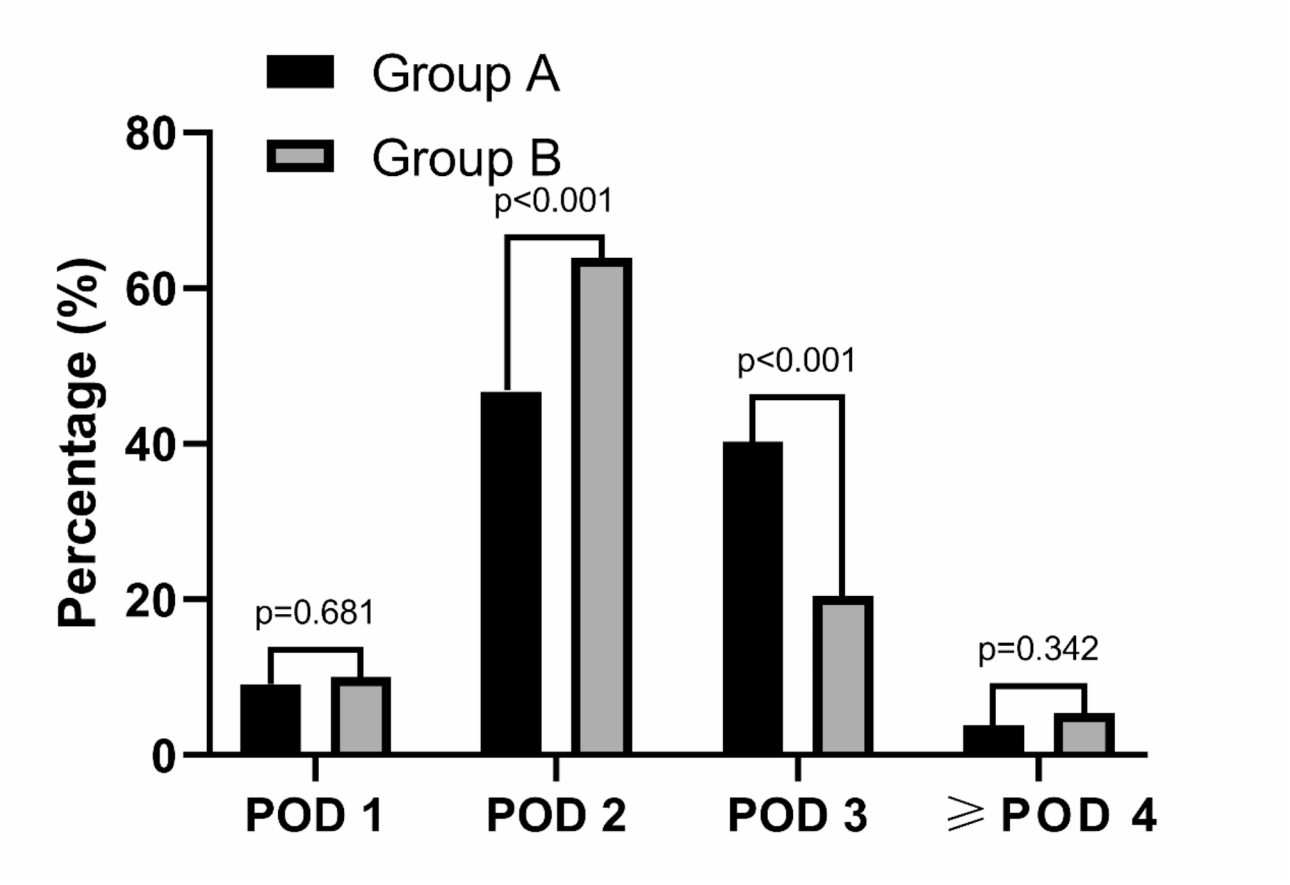

Fig. 2 Detailed information on the proportion of patients who met the criteria for early ambulation after surgery

Table 5 Multivariate logistic regression for overall complications

Risk factors	OR (95% CI)	*p*-value
Age	1.47 (0.94–2.38)	0.159
Female	0.85 (0.73–1.21)	0.867
BMI	1.41 (0.39–4.52)	0.741
INR	3.68 (0.58–8.37)	0.998
Smoking	1.11 (0.61–1.74)	0.368
Intraoperative blood loss	1.18 (0.99–1.65)	0.132
Surgical duration	2.17 (0.77–4.21)	0.140
Number of fused levels	3.24 (0.39–8.49)	0.155
Postoperative total drainage volume	1.38 (0.35–3.57)	0.847
Postoperative timing of ambulation	2.38 (1.19–3.97)	**< 0.001**

BMI: body mass index; INR: international normalized ratio; OR: odds ratio

have shown that 33–100% of patients undergoing lumbar decompression and fusion surgery have asymptomatic epidural hematoma, but the incidence of postoperative symptomatic epidural hematoma is only 0.1–0.24% [18, 19]. The small sample sizes of these RCT studies tend to cause practitioners to underestimate or even ignore the catastrophic consequences of symptomatic epidural hematoma. Furthermore, rescue surgery is not always timely due to various factors and patients with symptomatic hematoma usually need to be optimized to promote neurological recovery. Therefore, as a clinician, a majority decision is not advisable. Moreover, in a questionnaire study on the use of drainage in spinal surgeons and neurosurgeons in Germany, von Eckardstein et al. indicated that 69% of surgeons inclined to place drainage in patients undergoing hemilaminectomy for bilateral lumbar spinal stenosis and 88% of surgeons used to place drainage in patients undergoing posterior lumbar fusion with instrumentation [20].

Although most surgeons compromise to place drainage for fear of symptomatic hematoma, they agree on early drainage removal with the prevalent of ERAS in spine field [21, 22]. However, the criteria in discontinuing drainage in spinal surgery are heterogeneous and controversial. Some doctors remove the drainage on the second day regardless of the blood volume; some have variable drainage removal criteria (less than 50 or 100 ml per 24 h). Generally, the criteria for drainage removal is primarily determined by the volume of drainage, but there is no consensus on this protocol. Obviously, the standard of 50 ml seems to be strict, and a more lenient criterion would be more conducive to the early drainage removal. In our study, the incidence of symptomatic hematoma was 0.65%. Although comparable postoperative total drainage volume, more patients in group B tended to get

drainage removed on POD 2 and POD 3. Only 25.6% of patients in group A and 4.5% of patients in group B get drainage removed on POD 4, which was earlier than von Eckardstein et al. they reported that 98.5% of surgeons chose to remove drainage by POD 4 after posterior lumbar interbody fusion [20]. In addition, we found that more patients met the standard of early ambulation in group B. Accordingly, we found more patients ambulating on POD 2 in group B. Evidence suggested that as far as patients themselves are concerned, the insertion of a drain, whatever the pain, caused them anxiety and stress when moving or standing up, for fear of tearing it out, or of developing a complication due to the drainage [17, 23]. Consistent with previous studies, although more patients suffering from surgical site infection and symptomatic hematoma in group A, there was no significant difference [16, 24–26]. It is worth noting that 1 of 3 patients who suffering from symptomatic hematoma in group A required reoperation to remove the hematoma, and the postoperative neurological recovery was not incomplete due to delayed surgery and had to be transferred to a rehabilitation institution for further treatment. Furthermore, there were significant difference in overall complications between group A and group B. To determine potential risk factors associated with overall complications, we performed multivariate logistic regression and the result showed that the postoperative timing of ambulation was the only independent risk factor for overall complications. This indicated that the reduction in overall complications in group B was associated with earlier drainage removal, which enabling patients to ambulate earlier. The result was consistent with Wang et al., they demonstrated that early ambulation is independently associated with fewer adverse events in elderly patients undergoing elective transforaminal lumbar interbody fusion [13].

This study was not without limitations. First, this was a single-center, retrospective study without randomization. However, all the patients underwent surgeries by 5 experienced spine specialists to reduce the surgeon-specific difference. In addition, we performed propensity score matching to reduce the heterogeneity of enrolled patients. It is worthy noting that inevitable potential factors such as the surgeon' impression of intraoperative bleeding and hemostasis technique could affect the present study. Second, in the present study, patients with incomplete medical records had been excluded, which could introduce potential bias. Third, imaging data to assess the characteristic of epidural hematoma was not provided in our study. Identifying epidural hematoma by MRI is necessary, but time-consuming. For symptomatic epidural hematoma (progressive muscle strength decline, urinary incontinence, etc.), timely removal of hematoma is the key to avoid neurological deterioration and improve clinical efficacy. Finally, in this study, we found that early drainage removal could shorten the interval of early postoperative ambulation, thereby improving patients' clinical outcomes. There are two possible approaches to achieve early drainage removal. Firstly, we can consider using more lenient criteria for drainage removal, such as 150 ml even 200 ml per 24 h. Secondly, indeed, routine insertion of a drainage following short level lumbar fusion surgery may be not always required, but large-scale multicenter prospective studies are needed to confirm this. And a precise method, such as machine learning, should be employed to identify high-risk patients for postoperative hematoma, and drainage placement should be considered for these patients to achieve the purpose of precision medicine. More importantly, it is crucial to gradually change clinicians' concept regarding routine placement of drainage after spinal surgery.

Conclusion

In this study, we found that the relaxation of the criteria for drainage removal could significantly shorten the LOS, in addition, it could promote early postoperative ambulation of patients and thus reduce the occurrence of perioperative overall complications.

Abbreviations

POD	Postoperative day
LOS	Length of stay
ERAS	Enhanced recovery after surgery
PLIF	Posterior lumbar interbody fusion
TLIF	Transforaminal lumbar interbody fusion
BMI	Body mass index
RBC	Red blood cell
INR	International normalized ratio

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Author contributions

Peng Cui mainly contributed to the conception of the study and wrote the manuscript. Di Han, Xiao-Long Chen and Peng Wang contributed to the study design and data review. Shi-Bao Lu made an important contribution to the revision of the manuscript.

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Data availability

The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethical review committee of Xuanwu Hospital, Capital Medical University (IRB#2018086), and all methods were carried out

under relevant guidelines and regulations. Written informed consent was obtained from all the enrolled patients in this study. Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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