Analysis of Risk Factors Associated with Hospital Readmission Within 360 Days After Degenerative Lumbar Spine Surgery in Elderly Patients

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■ OBJECTIVE: **There is a paucity of studies on readmission rates in elderly patients over a period of 360 days after spinal surgery.**

■ METHODS: **We identified 1248 patients older than 70 years who underwent degenerative lumbar spinal surgery from November 2005 to April 2015. We reviewed the patients who were readmitted within 360 days and compared them by univariate and multivariate analysis with the nonreadmitted patients for each period of 0–30, 30–90, 90–180, and 180–360 days postoperatively to determine risk factors for hospital readmission.**

■ RESULTS: **A total of 1248 patients (733 female, 58.7%) were enrolled in the study. The number of readmitted patients was 37 (2.96%), 94 (7.53%), 145 (11.62%), 182 (14.58%), and 213 (17.07%) at 30, 90, 180, 270, and 360 days, respectively. Surgical site–related problems decreased gradually in the first 0–90 days and slightly increased after then. Non-surgical site–related problems gradually increased with time. Logistic multiple regression analysis showed that electrocardiographic abnormalities, male sex, low hemoglobin levels, asthma, heart disease, intensive care unit admission, low alanine aminotransferase level, high body mass index, and high platelet level were risk factors for readmission.**

■ CONCLUSIONS: **We found that electrocardiographic abnormalities, male sex, low hemoglobin levels, asthma, heart disease, intensive care unit admission, low aspartate aminotransferase level, high body mass index, and high platelet level were risk factors for readmission. As the postoperative observational period became longer, the reasons for readmission tended to be more related to non-surgical site–related problems than to surgical-related problems.**

INTRODUCTION

With the increase in the elderly population, the number of patients with degenerative spine disease and undergoing surgery is expected to increase.[1-5] The development of surgical and anesthetic techniques also makes it possible to perform more surgeries for older patients with more comorbidities. However, it is accompanied by an increase in the number of complications, morbidity, and mortality.[6-8] This situation has resulted in an increase in hospital readmission rate and medical costs. Recently, the Centers for Medicare and Medicaid Services set a 30-day readmission rate as the target for unnecessary cost reduction and have used it as an important quality indicator of hospital performance. Hospital readmission is becoming not only an important quality indicator of hospital care but also a criterion for penalizing hospitals with excessive readmission rates.[9-12] According to a previous report, about 80% of hospitals would receive reduced payments and 19% would be penalized for excessive readmission rates by the Hospital Readmission Reduction Program, as part of the Affordable Care Act, in 2017.[13] Spine surgery is an area in which medical costs are high and it is anticipated that this readmission reduction program may be extended to spine surgery.[13,14] For that reason, it is important to

Key words
- Elderly patients
- Readmission
- Regression analysis
- Risk factors
- Spinal surgery

Abbreviations and Acronyms
ASA: American Society of Anesthesiologists
BMI: Body mass index
EKG: Electrocardiography
ICU: Intensive care unit
LOS: Length of stay
OR: Odds ratio

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investigate hospital readmission rates and find out the modifiable risk factors to prevent them before surgery, especially in elderly patients, who frequently undergo degenerative spinal surgery.

Several studies of readmission rates after spinal surgery have been carried out recently, showing the readmission rate and various modifiable causes for readmission. However, there is a paucity of studies on readmission rates in elderly patients over a period of 360 days after spinal surgery. Most of the studies were conducted mainly on the 30-day and 90-day readmission rates using nationwide administrative database data. It is likely that a longer period than 30 or 90 days will provide more information to improve patient care. For example, complications such as adjacent segment disease and pseudarthrosis can be found at a longer postoperative follow-up period.[3] Because the elderly population is affected not only by the surgical factors but also by age-related diseases, the comprehensive risk factor analysis of the longer-term 360-day readmission rate as well as the 30-day readmission rate is meaningful in terms of individual elderly patient health evaluation.

Therefore, we conducted a retrospective study using a single institution's database data in the geriatric population older than 70 years, which accounts for most patients undergoing degenerative spinal surgeries. We investigated readmission rates after 30, 90, 180, and 360 days and aimed to identify the risk factors and causes of readmission for each period.

METHODS

Patient Population

We initially identified 6905 patients who underwent degenerative lumbar spinal surgery from a single tertiary-institution registry database from November 2005 to April 2015. Of these patients, patients older than 70 years who were able to be followed up for more than 360 days were included. Patients with tumors, deformities, trauma, or infection were excluded (Figure 1).

Definition of Readmission and Reasons for Readmission

We considered the first spinal surgery in our database as index surgery during the study period and determined the readmission date from this index surgery. Reasons for readmission were classified as follows: 1) surgical site related problem, 2) non-surgical site—related problem, 3) pain, 4) other level spine problems. Surgical site—related problems included surgical site infection, hematoma, cerebrospinal fluid (CSF) collection, recurrence, and instrument failures. Non-surgical site—related problems included major organ problems, such as cardiac, respiratory, and neurologic problems, and minor organ problems, such as deep vein thrombosis, delirium, gastrointestinal, genitourinary, orthopedic, and ophthalmologic problems.

Data Collection and Analysis

Clinical factors such as sex, age, body mass index (BMI), and American Society of Anesthesiologists (ASA) physical status classification score at the index surgery were investigated in each patient's chart review. Comorbidities such as hypertension, diabetes mellitus, and asthma were investigated and laboratory data such as hemoglobin and platelet levels at the index surgery were also collected retrospectively. Surgical factors such as method of surgery, number of operation level, operative time, and other hospital factors such as cost, intensive care unit (ICU) admission, and length of stay (LOS) were also investigated.

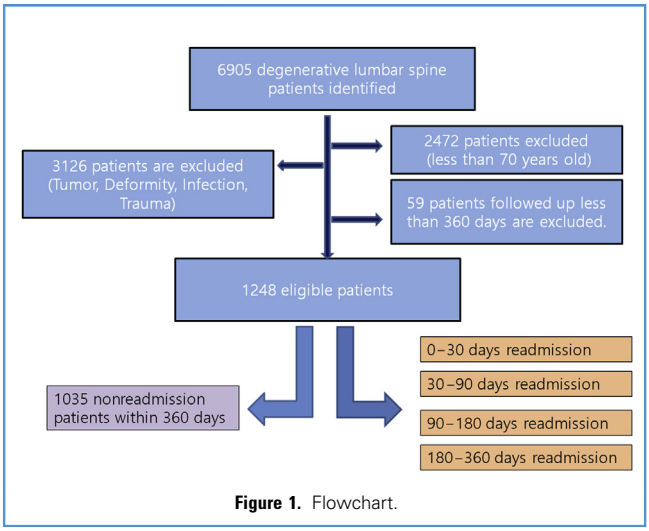

Figure 1. Flowchart.

Based on the readmission status within 360 days, we reviewed the patients who were readmitted in each period and compared them by univariate and multivariate analysis with the non-readmitted patients for each period of 0—30, 30—90, 90—180, and 180—360 days postoperatively.

Statistical Analysis

Descriptive statistics were used for patient's characteristics, comorbidities, and laboratory data. A Student t test and Mann-Whitney test were used for continuous variables; χ^2 and Fisher exact tests were used for categorical variables. Univariate and multivariate logistic regression was performed to determine the risk factors on postoperative 0—30, 30—90, 90—180, and 180—360 days readmission. All the variables were included in the multivariate analysis. All statistical comparisons were considered significant with a P value <0.05. Statistical analyses were performed using SPSS version 18 (IBM Corp., Armonk, New York, USA).

RESULTS

A total of 1248 patients (733 female, 58.7%) were enrolled in the study. Of these patients, 213 (17.07%) were readmitted within 360 days from the index surgery. The mean age of the patients was 74.14 ± 3.64 years. The number of readmission patients was 37 (2.96%), 94 (7.53%), 145 (11.62%), 182 (14.58%), and 213 (17.07%) at 30, 90, 180, 270, and 360 days, respectively. Readmission rates gradually decreased over time (Figure 2, Table 1).

Regarding the proportion of postoperative readmission causes by period (Figure 3A and B and Table 2), the proportion of surgical site—related problems decreased gradually in the first 0—90 days and then slightly increased in readmissions during the 181—270 and 271—360 days period. On the contrary, the proportion of non-surgical site—related problems gradually increased with time. Readmissions because of pain were stable throughout the 0—30 and 31—90 day periods and decreased throughout the 181—270 and 271—360 day readmission period. Readmissions because of other level spine-related issues gradually increased with time.

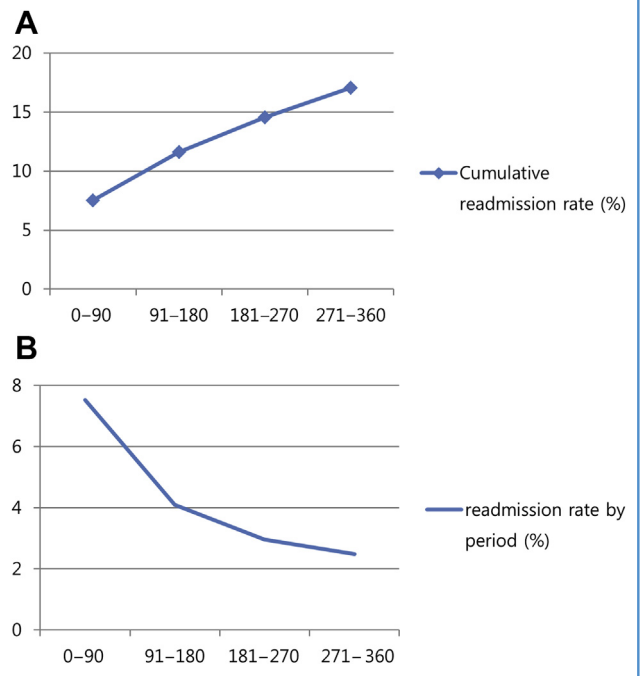

Figure 2. (**A**) Cumulative readmission rate and (**B**) readmission rate by period.

The logistic multiple regression analysis (Table 3) showed that in the first 30 days, only electrocardiographic (EKG) abnormalities (odds ratio [OR], 6.371; P = 0.000) were a statistically significant risk factor. For readmission at 30–90 days, male sex (OR, 0.411; P = 0.022), hemoglobin levels (OR, 0.758; P = 0.025), asthma (OR, 7.400; P = 0.000), heart disease (OR, 4.023; P = 0.000), and ICU admission (OR, 4.597; P = 0.005) were added as significant risk factors. In the 90–180 days readmission period, male sex (OR, 0255; P = 0.001) and alanine aminotransferase values (OR, 0.882; P = 0.007) were significant risk factors. Male sex (OR, 0.395; P = 0.005), BMI (OR, 1.126; P = 0.005), hemoglobin levels (OR, 0.787; P = 0.036), and platelet count (OR, 1.006; P = 0.004) were risk factors for readmission after 180–360 days.

DISCUSSION

We calculated the 30, 90, 180, and 360 days readmission rates from a total of 1248 patients. The number of readmitted patients was 37 (2.96%), 94 (7.53%), 145 (11.62%), 182 (14.58%), and 213 (17.07%) within 30, 90, 180, 270, and 360 days, respectively. Readmission rates gradually decreased over time. The 30-day readmission rate was 2.96% in this study, which was lower than in previous studies (5.5% in Bernatz et al.,[14] 7.3% in Wang et al.,[15] and 4.4% in Kim et al.[12]) Because of the heterogeneity of studies, a direct comparison was difficult. However, although this study targeted elderly patients aged >70 years, one of the reasons why this study shows a lower 30-day readmission rate might be that in medical institutions in Korea, the LOS is usually longer than in other countries such as the United States. As shown in the present study, LOS was 11.51 ± 7.07 days, which is longer than that of Parker et al.'s study.[10] Under the different medical insurance system, there is a possibility that the 30-day readmission rate in Korea is lower than that of the United States because of the longer LOS after index surgery in Korea.

In this study, non-surgical site–related problems were the most common reason for readmission after 0–30 days, followed by surgical site–related problems. Non-surgical site–related problems remained as the most common cause for readmission throughout the study period. This result is different from previous research results. In a 90-day readmission study by Hills et al.,[13] surgical site–related complications were the most common reason, followed by medical complications and pain. Bernatz et al.'s meta-analysis[14] identified infection as the most common cause for readmission, with a rate of 28.2%, followed by medical complications, with a rate of 26.6%. On the other hand, Parker et al.[10] reported that the most common cause for readmission (52.9% of patients) within 90 days was a medical-related problem. The result of this study might be caused by the different study population compared with the previous studies. Previous studies have shown that the elderly population has more underlying diseases and therefore more postoperative medical complications.[16-19] Julia et al.[17] reported that 215 patients (88%) had a preoperative medical disorder in a sample of 244 patients who underwent lumbar decompression surgery at >80 years of age, and 17 patients (7.0%) had postoperative medical complications, including 4 pulmonary embolisms, 6 pneumonias, 3 myocardial infarctions, 1 postoperative renal failure, and 5 urinary tract infections. Of these complications, 14 (73.7%) showed severe progression. In Jakola et al.,[18] 100 patients older than 70 years who underwent lumbar decompressive laminectomy reported 4 medical complications out of a total of 9 complications, excluding intraoperative dura tears. When considering surgery for patients aged 70 years or older, a closer examination of the medical comorbidities is needed and it is important to recognize the high possibility of non-spine-related complications in the elderly population.

We also analyzed the median time of readmission according to the readmission cause; surgical site–related problems occurred at a median time of 48.00 days, whereas non-surgical site–related problems occurred at a median time of 143.00 days, pain problems occurred at a median time of 68.00 days, and other level spine-related problems occurred at a median time of 165.00 days. Compared with the previous study by Hills et al.[13], which analyzed readmissions over 90 days, we conducted a longer-term analysis for various readmission causes including other level spine problems. In cases of non-surgical site–related problems and other spinal problems, especially in the elderly population, careful long-term postsurgical observation is necessary (Figure 4 and Table 4).

As seen in the multiple logistic regression analysis of risk factors associated with 0–30 days readmission, surgical variables such as operative method, operative time, and operative number of level were not risk factors for readmission; only EKG abnormalities were found to be a risk factor in this period (OR, 6.259; P = 0.000) In addition, 30–90 days, 90–180 days, 180–270 days, and 270–360 days analyses did not show any surgical variables as related risk factors for readmission. The factors found to be associated with readmission were sex, EKG abnormality,

Table 1. Patients' Characteristics, Comorbidities, Operative Variables, and Other Factors Associated with Hospital Readmission within 360 Days

Variable	Total (N = 1248)	Nonreadmission Group (N=1035)	Readmission Group (N=213)	*P* Value
Characteristics				
Age (years), mean ± SD	74.14 ± 3.64	74.13 ± 3.66	74.38 ± 3.55	**0.027**
Male (%)	515 (41.3)	409 (39.5)	106 (49.8)	**0.006**
Body mass index (kg/m^2), mean ± SD	24.02 ± 3.21	24.00 ± 3.08	24.03 ± 3.62	0.573
Comorbidities				
Asthma (%)	47 (3.8)	34 (3.3)	13 (6.1)	0.072
Neurologic disease (%)	10 (1.0)	8 (1.0)	2 (1.1)	0.697
Diabetes mellitus (%)	160 (12.8)	132 (12.8)	28 (13.1)	0.910
Drug allergy (%)	3 (0.2)	2 (0.2)	1 (0.5)	0.430
Cardiovascular accident history (%)	90 (7.2)	72 (7.0)	18 (8.5)	0.467
Heart disease (%)	177 (14.2)	125 (12.1)	52 (24.4)	**0.000**
Hypertension (%)	787 (63.1)	654 (63.2)	133 (62.4)	0.876
Hepatitis (%)	13 (1.0)	11 (1.1)	2 (0.9)	1.000
Pulmonary tuberculosis (%)	57 (4.6)	46 (4.4)	11 (5.2)	0.718
Renal disease (%)	10 (1.0)	10 (1.3)	0 (0.0)	0.224
Laboratory data				
Alanine aminotransferase (IU/L), mean ± SD	20.54 ± 10.17	20.48 ± 10.33	20.05 ± 8.46	0.756
Aspartate aminotransferase (IU/L), mean ± SD	21.35 ± 7.04	21.36 ± 7.19	20.88 ± 6.19	0.261
Blood urea nitrogen (mg/dL), mean ± SD	17.95 ± 6.29	17.86 ± 6.42	18.54 ± 6.00	0.128
Creatinine (mg/dL), mean ± SD	0.919 ± 0.57	0.91 ± 0.62	0.94 ± 0.31	**0.010**
Hemoglobin (g/dL), mean ± SD	13.08 ± 1.41	13.13 ± 1.38	12.75 ± 1.46	**0.011**
Platelets ($10^3/\mu L$), mean ± SD	251.50 ± 68.20	249.27 ± 66.50	264.04 ± 75.20	0.091
Operative variables and other factors				
Abnormal simple chest radiograph (%)	425 (34.1)	356 (34.4)	69 (32.4)	0.580
Abnormal electrocardiograph (%)	211 (17.3)	165 (16.2)	46 (22.3)	**0.043**
American Society of Anesthesiologists classification				0.499
1 (%)	368 (30.2)	305 (30.2)	63 (30.6)	
2 (%)	553 (45.4)	467 (46.2)	86 (41.7)	
3 (%)	289 (23.7)	234 (23.1)	55 (26.7)	
4 (%)	7 (0.6)	5 (0.5)	2 (1.0)	
Surgical procedure				**0.023**
Laminectomy (%)	480 (38.5)	385 (37.2)	95 (44.6)	
Posterolateral fusion+posterior lumbar interbody fusion + transforaminal lumbar interbody fusion (%)	739 (59.2)	626 (60.5)	114 (53.5)	
Direct lumbar interbody fusion (%)	15 (1.2)	15 (1.4)	0 (0.0)	
Anterior lumbar interbody fusion (%)	14 (1.4)	9 (0.9)	4 (1.9)	

Bold values indicate statistical significance ($P < 0.05$).
SD, standard deviation.
*U.S. dollar (USD) and Korean won (KRW) exchange rate: 1USD=1115.50KRW.

Continues

Table 1. Continued

Variable	Total (N = 1248)	Nonreadmission Group (N=1035)	Readmission Group (N=213)	*P* Value
Surgical level				**0.021**
1	730 (58.5)	593 (57.3)	137 (64.3)	
2	399 (32.0)	336 (32.5)	63 (29.6)	
3	102 (8.2)	93 (9.0)	9 (4.2)	
4–6	17 (1.4)	13 (1.3)	4 (1.9)	
Postoperative blood transfusion (%)	238 (19.2)	196 (19.0)	42 (19.8)	0.848
Operative time (minutes), mean ± SD	169.87 ± 93.80	171.89 ± 96.20	166.73 ± 82.82	0.110
Intensive care unit admission (%)	77 (6.2)	51 (4.9)	26 (12.2)	**0.000**
Cost (U.S. dollars), mean ± SD*	7944.79 ± 4110.02	7821.54 ± 3372.93	8758.85 ± 6319.91	0.251
Length of stay (days), mean ± SD	11.51 ± 7.07	11.18 ± 6.62	13.09 ± 8.80	**0.000**
Disposition destination (%)				0.065
Home	1184 (95.5)	986 (95.9)	198 (93.4)	
Other hospital	50 (4.0)	38 (3.7)	12 (5.7)	
Care facility	3 (0.2)	1 (0.1)	2 (0.9)	
Others	3 (0.2)	3 (0.3)	0 (0)	
Type of insurance status (%)				0.126
Medicare	1211 (97.0)	1002 (96.8)	209 (98.1)	
Medicaid	35 (2.8)	32 (3.1)	3 (1.4)	
Others	2 (0.2)	1 (0.1)	1 (0.5)	

Bold values indicate statistical significance ($P < 0.05$).
SD, standard deviation.
*U.S. dollar (USD) and Korean won (KRW) exchange rate: 1USD=1115.50KRW.

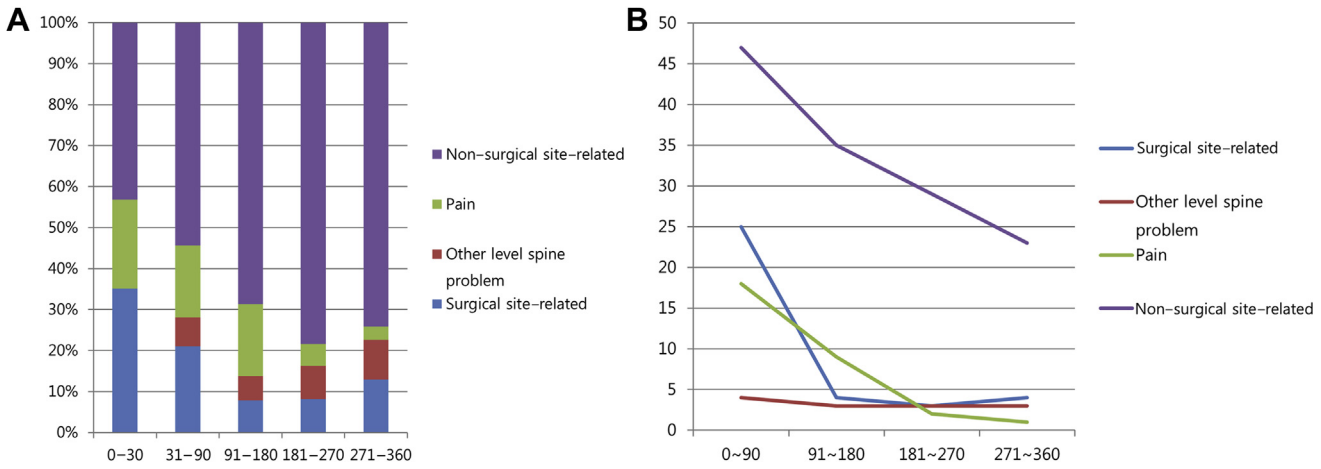

Figure 3. (**A**) Causes of hospital readmission by period. (**B**) Number readmissions by period.

Table 2. Causes of Hospital Readmission and the Number of Readmissions by Period

	0–30 days, n (%)	31–90 days, n (%)	91–180 days, n (%)	181–270 days, n (%)	271–360 days, n (%)	Total
Surgical site–related	13 (35)	12 (21)	4 (8)	3 (8)	4 (13)	36 (17)
Infection	7 (19)	3 (5)	0 (0)	0 (0)	1 (3)	11 (5)
Hematoma, cerebrospinal fluid collection, recurrence, seroma, wound dehiscence	6 (16)	7 (12)	4 (8)	3 (8)	3 (10)	23 (11)
Instrument failure (loosening, malposition)	0 (0)	2 (4)	0 (0)	0 (0)	0 (0)	2 (1)
Other level spine problem	0 (0)	4 (7)	3 (6)	3 (8)	3 (10)	13 (6)
Pain	8 (22)	10 (18)	9 (18)	2 (5)	1 (3)	30 (14)
Non-surgical site–related	16 (43)	31 (54)	35 (69)	29 (78)	23 (74)	134 (63)
Cardiac, respiratory, neurological	3 (8)	12 (21)	8 (16)	6 (16)	12 (39)	41 (19)
Deep vein thrombosis, delirium	3 (8)	3 (5)	1 (2)	1 (3)	0 (0)	8 (4)
Other organs	10 (27)	16 (28)	26 (51)	22 (59)	11 (35)	85 (40)
Total	37	57	51	37	31	213

asthma, heart disease, hemoglobin levels, BMI, alanine aminotransferase levels, platelet count, and ICU admission. In a study of patients who underwent noncardiac surgery, Noordzij et al.[20] reported that patients with abnormal EKG findings had a higher incidence of cardiovascular death than did patients with normal EKG findings (1.8% vs. 0.3%; adjusted OR, 4.5; 95% confidence interval, 3.3–6.0) and preoperative EKG provided prognostic information in combination with clinical characteristics and type of surgery. Deyo et al.[2] reported that the readmission rate was higher for more complex fusion and multiple-level fusion surgery. However, there was no association between operative number of level and readmission rate in this study. This finding might be because the surgeons have chosen a less invasive surgical procedure depending on the patient's condition, as opposed to Saleh et al.'s study.[3] This situation might be a result of the reduction of the operative range when it is judged that the general condition of the patient is poor. However, this study could not show any association between range of surgical procedure and the general condition of the patient.

Age was not a significant risk factor for readmission in this study. Jansson et al.[21] reported that age as a risk factor of readmission varies depending on age, with the lowest risk between 50 and 69 years. In elderly patients >70 years of age, there might be more practical factors reflecting patient's physiologic age, such as a frailty score rather than a chronologic age.

Regarding the influence of sex, male patients were more susceptible to readmission in all periods after 30 days. However, according to the existing literature, sex as a risk factor for readmission differs among studies.

Previous studies have attempted to identify the impact of comorbidities as risk factors for readmission within 30 days after degenerative spine surgery. Kim et al.[12] reported a 30-day readmission rate of 4.4% in a study of 7016 patients with lumbar decompression using a national database. These investigators reported that anemia (OR, 1.48), dependent functional status (OR, 3.03), total operative time (OR, 1.003), and ASA class 4 (OR, 3.61) were risk factors for readmission. In a multicenter study of 15,668 spine surgeries by Pugely et al.,[22] 695 patients (4.4%) were readmitted within 30 days. Age >80 years ($P = 0.03$), African American race ($P = 0.03$), recent weight loss ($P = 0.04$), history of chronic obstructive pulmonary disease ($P < 0.01$), history of cancer ($P = 0.04$), serum creatinine level >1.2 mg/dL ($P < 0.01$), increased ASA class ($P = 0.01$), operative time of >4 hours ($P = 0.01$), and prolonged hospital LOS ($P < 0.01$) were the risk factors found. Hills et al.[13] reported a history of myocardial infarction, osteoporosis, higher baseline leg and arm pain scores, longer operative duration, and surgery as risk factors for readmission. According to a study by Aladine et al.[9] using a nationwide database, readmission rates were 5.0% and 2.3% at 30 days and at 30–90 days after elective lumbar spine surgery, respectively. These investigators reported that age, insurance status, hypertension, diabetes, anemia, obesity, and depression were associated with unplanned hospital readmission. Because of the heterogeneity of these studies, risk factors for readmission cannot be directly compared with each other. However, we found that the patients' comorbidities mentioned in the previous literature accounted for most of the risk factors in this study.

Limitations of This Study

There are some limitations to this study. First, in this study, readmission is not limited to unplanned readmission but includes planned readmission. However, the number of planned readmissions was low. In most cases, the hospitalization period was extended instead of readmitting the patient. Second, because this study is based on single-center database data, the

Table 3. Risk Factors Associated with Hospital Readmission After Spine Surgery by Period

	Univariate Analysis		Multivariate Analysis	
Variable	**Odds Ratio (95% Confidence Interval)**	***P* Value**	**Odds Ratio (95% Confidence Interval)**	***P* Value**
0–30 days				
Sex	1.206 (0.607–2.396)	0.592	1.403 (0.489–4.027)	0.529
Age	1.081 (0.996–1.173)	0.062	1.063 (0.946–1.194)	0.306
BMI	0.962 (0.865–1.070)	0.473	0.986 (0.843–1.113)	0.650
OP method		0.646		0.397
D-lami	Reference		Reference	
PLIF, PLF	0.649 (0.337–1.252)		0.400 (0.141–1.135)	
DLIF	0.000		0.000	
ALIF	0.000		0.000	
Number of OP level	0.887 (0.551–1.427)	0.620	0.664 (0.301–1.464)	0.310
OP time	1.000 (0.996–1.003)	0.821	1.001 (0.996–1.007)	0.692
ALT	1.006 (0.976–1.036)	0.708	1.008 (0.959–1.058)	0.761
AST	0.988 (0.938–1.041)	0.648	1.000 (0.927–1.078)	0.990
BUN	1.035 (0.994–1.079)	0.099	1.057 (0.976–1.145)	0.172
Cr	0.933 (0.471–1.847)	0.842	0.736 (0.227–2.359)	0.611
Hemoglobin	0.854 (0.676–1.079)	0.186	0.890 (0.639–1.239)	0.489
Platelet	1.001 (0.996–1.006)	0.834	1.001 (0.994–1.007)	0.840
ASA classification		0.949		0.824
1	Reference		Reference	
2	1.234 (0.543–2.803)		0.917 (0.356–2.359)	
3	1.303 (0.509–3.335)		0.494 (0.110–2.228)	
4	0.000		0.000	
CXR	0.916 (0.455–1.844)	0.805	0.667 (0.262–1.700)	0.396
EKG	**3.442 (1.715–6.908)**	**0.001**	**6.371 (2.446–16.596)**	**0.000**
Asthma	**4.600 (1.688–12.537)**	**0.003**	3.010 (0.609–14.881)	0.177
Neurologic disease	0.000	0.999	0.000	0.999
DM	0.829 (0.289–2.378)	0.728	0.909 (0.158–5.237)	0.915
Drug allergy	0.000	0.999	0.000	1.000
CVA	1.621 (0.559–4.703)	0.374	0.625 (0.099–4.307)	0.657
Heart disease	1.699 (0.731–3.949)	0.218	1.618 (0.502–5.213)	0.420
HTN	0.765 (0.394–1.483)	0.427	0.515 (0.216–1.227)	0.134
Hepatitis	0.000	0.999	0.000	0.999
Pulmonary tbc	0.000	0.998	0.000	0.998
Renal disease	0.000	0.999	0.000	0.999
Cost	1.000 (1.000–1.000)	0.372	1.000 (1.000–1.000)	0.265
ICU admission	1.103 (0.258–4.712)	0.895	1.826 (0.313–10.663)	0.504
LOS	1.008 (0.963–1.054)	0.745	0.961 (0.873–1.059)	0.425

Continues

Table 3. Continued

	Univariate Analysis		Multivariate Analysis	
Variable	**Odds Ratio (95% Confidence Interval)**	***P* Value**	**Odds Ratio (95% Confidence Interval)**	***P* Value**
30–90 days				
Sex	**0.548 (0.321–0.936)**	**0.028**	**0.411 (0.192–0.879)**	**0.022**
Age	**1.073 (1.004–1.146)**	**0.037**	1.014 (0.929–1.107)	0.755
BMI	1.000 (0.919–1.089)	1.000	1.013 (0.912–1.126)	0.806
OP method		0.580		0.979
D-lami	Reference		Reference	
PLIF, PLF	0.710 (0.413–1.218)		0.851 (0.356–2.031)	
DLIF	0.000		0.000	
ALIF	1.645 (0.201–13.487)		1.138 (0.080–16.256)	
Number of OP level	0.833 (0.560–1.238)	0.365	0.601 (0.314–1.151)	0.125
OP time	0.999 (0.996–1.003)	0.660	0.999 (0.992–1.005)	0.648
ALT	1.002 (0.977–1.028)	0.861	1.002 (0.963–1.043)	0.915
AST	1.009 (0.976–1.043)	0.604	0.983 (0.927–1.043)	0.570
BUN	1.018 (0.980–1.058)	0.361	1.003 (0.947–1.064)	0.907
Cr	1.181 (0.894–1.560)	0.241	0.923 (0.462–1.844)	0.820
Hemoglobin	**0.792 (0.654–0.958)**	**0.017**	**0.758 (0.594–0.966)**	**0.025**
Platelet	1.000 (0.996–1.004)	0.994	1.002 (0.997–1.007)	0.389
ASA classification		0.606		0.494
1	Reference		Reference	
2	0.980 (0.512–1.874)		0.723 (0.339–1.539)	
3	1.222 (0.592–2.522)		0.407 (0.130–1.275)	
4	3.812 (0.420–34.584)		0.000	
CXR	0.880 (0.496–1.561)	0.603	0.632 (0.307–1.304)	0.215
EKG	1.721 (0.919–3.223)	0.090	**4.147 (1.883–9.134)**	**0.000**
Asthma	**4.122 (1.741–9.756)**	**0.001**	**7.400 (2.418–22.648)**	**0.000**
Neurologic disease	2.055 (0.252–16.765)	0.501	1.796 (0.172–18.756)	0.625
DM	1.283 (0.615–2.675)	0.507	1.274 (0.380–4.276)	0.695
Drug allergy	0.000	0.999	0.000	1.000
CVA	1.009 (0.355–2.868)	0.986	0.959 (0.247–3.727)	0.952
Heart disease	**3.935 (2.214–6.995)**	**0.000**	**4.023 (1.880–8.612)**	**0.000**
HTN	1.078 (0.617–1.884)	0.793	1.092 (0.529–2.256)	0.812
Hepatitis	3.385 (0.732–15.647)	0.118	6.004 (0.854–42.205)	0.072
Pulmonary tbc	0.384 (0.052–2.835)	0.348	0.000	0.998
Renal disease	0.000	0.999	0.000	0.999
Cost	**1.000 (1.000–1.000)**	**0.009**	1.000	0.948
ICU admission	**5.701 (2.889–11.249)**	**0.000**	**4.597 (1.590–13.289)**	**0.005**
LOS	**1.047 (1.023–1.072)**	**0.000**	1.041 (0.981–1.104)	0.189

Bold values indicate statistical significance ($P < 0.05$).

BMI, body mass index; OP, operation; D-lami, decompressive laminectomy; PLIF, posterior lumbar interbody fusion; PLF, posterolateral fusion; DLIF, direct lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; Cr, creatinine; ASA, American Society of Anesthesiologists; CXR, chest simple radiography; EKG, electrocardiogram; DM, diabetes mellitus; CVA, cerebrovascular accident; HTN, hypertension; tbc, tuberculosis; ICU, intensive care unit; LOS, length of stay.

Continues

Table 3. Continued

	Univariate Analysis		Multivariate Analysis	
Variable	**Odds Ratio (95% Confidence Interval)**	***P* Value**	**Odds Ratio (95% Confidence Interval)**	***P* Value**
90–180 days				
Sex	**0.457 (0.258–0.810)**	**0.007**	**0.255 (0.111–0.586)**	**0.001**
Age	1.028 (0.954–1.108)	0.469	0.967 (0.869–1.075)	0.533
BMI	0.919 (0.837–1.009)	0.076	0.913 (0.801–1.040)	0.169
OP method		0.283		0.073
D-lami	Reference		Reference	
PLIF, PLF	0.892 (0.497–1.599)		2.617 (0.818–8.370)	
DLIF	0.000		0.000	
ALIF	4.278 (0.866–21.119)		23.505 (2.211–249.855)	
Number of OP level	1.041 (0.714–1.518)	0.836	1.107 (0.576–2.129)	0.760
OP time	0.998 (0.994–1.002)	0.280	0.995 (0.987–1.004)	0.269
ALT	0.984 (0.953–1.015)	0.304	1.026 (0.975–1.081)	0.323
AST	0.954 (0.905–1.005)	0.076	**0.882 (0.805–0.967)**	**0.007**
BUN	1.019 (0.979–1.060)	0.360	1.006 (0.940–1.076)	0.873
Cr	1.105 (0.780–1.566)	0.574	0.869 (0.408–1.852)	0.716
Hemoglobin	0.934 (0.763–1.145)	0.512	0.846 (0.648–1.102)	0.215
Platelet	1.003 (0.998–1.007)	0.235	1.004 (0.999–1.008)	0.158
ASA classification		0.463		0.290
1	Reference		Reference	
2	1.089		1.445 (0.598–3.496)	
3	1.738		3.456 (0.974–12.254)	
4	0.000		0.000	
CXR	0.722 (0.385–1.353)	0.309	0.644 (0.287–1.444)	0.285
EKG	1.033 (0.475–2.247)	0.935	0.682 (0.180–2.586)	0.573
Asthma	0.000	0.998	0.000	0.998
Neurologic disease	2.466 (0.301–20.195)	0.400	3.997 (0.329–48.575)	0.277
DM	1.466 (0.697–3.081)	0.313	0.892 (0.262–3.040)	0.855
Drug allergy	0.000	0.999	0.000	1.000
CVA	1.138 (0.399–3.248)	0.809	0.318 (0.041–2.499)	0.276
Heart disease	1.776 (0.868–3.634)	0.116	1.724 (0.653–4.549)	0.272
HTN	1.165 (0.642–2.114)	0.615	1.204 (0.507–2.858)	0.674
Hepatitis	0.000	0.999	0.000	0.999
Pulmonary tbc	1.830 (0.632–5.296)	0.265	1.507 (0.331–6.850)	0.596
Renal disease	0.000	0.999	0.000	0.999
Cost	1.000 (1.000–1.000)	0.687	1.000 (1.000–1.000)	0.111
ICU admission	1.206 (0.363–4.003)	0.760	2.025 (0.483–8.494)	0.335
LOS	**1.030 (1.004–1.057)**	**0.026**	1.075 (0.997–1.160)	0.061

Continues

Table 3. Continued

	Univariate Analysis		Multivariate Analysis	
Variable	**Odds Ratio (95% Confidence Interval)**	***P* Value**	**Odds Ratio (95% Confidence Interval)**	***P* Value**
180–360 days				
Sex	0.735 (0.449–1.202)	0.220	**0.395 (0.206–0.758)**	**0.005**
Age	1.014 (0.949–1.084)	0.685	1.015 (0.940–1.097)	0.698
BMI	**1.085 (1.015–1.161)**	**0.017**	**1.126 (1.036–1.223)**	**0.005**
OP method		0.575		0.797
D-lami	Reference		Reference	
PLIF, PLF	0.714 (0.435–1.174)		0.702 (0.339–1.455)	
DLIF	0.000		0.000	
ALIF	1.380 (0.169–11.248)		1.060 (0.106–10.579)	
Number of OP level	**0.582 (0.377–0.897)**	**0.014**	0.640 (0.365–1.120)	0.118
OP time	0.999 (0.996–1.002)	0.673	1.000 (0.996–1.004)	0.998
ALT	0.996 (0.971–1.021)	0.728	0.997 (0.961–1.036)	0.895
AST	0.996 (0.961–1.033)	0.843	1.016 (0.965–1.070)	0.543
BUN	1.000 (0.961–1.041)	0.999	1.010 (0.954–1.069)	0.741
Cr	1.024 (0.694–1.511)	0.904	0.826 (0.399–1.710)	0.606
Hemoglobin	0.860 (0.720–1.027)	0.095	**0.787 (0.629–0.984)**	**0.036**
Platelet	**1.004 (1.000–1.007)**	**0.029**	**1.006 (1.002–1.010)**	**0.004**
ASA classification		0.308		0.328
1	Reference		Reference	
2	0.628 (0.356–1.108)		0.707 (0.369–1.357)	
3	0.752 (0.389–1.452)		0.733 (0.255–2.111)	
4	2.346 (0.264–20.839)		5.768 (0.360–92.379)	
CXR	1.109 (0.666–1.845)	0.691	0.662 (0.351–1.250)	0.203
EKG	0.906 (0.453–1.810)	0.780	1.096 (0.426–2.823)	0.849
Asthma	0.439 (0.059–3.260)	0.421	0.502 (0.059–4.299)	0.530
Neurologic disease	0.000	0.999	0.000	0.999
DM	0.662 (0.281–1.561)	0.346	0.358 (0.071–1.805)	0.213
Drug allergy	7.709 (0.690–86.101)	0.097	7.714 (0.367–162.086)	0.189
CVA	1.294 (0.541–3.094)	0.562	1.546 (0.524–4.563)	0.430
Heart disease	**2.060 (1.127–3.765)**	**0.019**	2.121 (0.949–4.738)	0.067
HTN	0.885 (0.536–1.461)	0.632	0.652 (0.348–1.220)	0.181
Hepatitis	0.000	0.999	0.000	0.999
Pulmonary tbc	2.081 (0.856–5.060)	0.106	1.580 (0.478–5.222)	0.454
Renal disease	0.000	0.999	0.000	0.999
Cost	**1.000 (1.000–1.000)**	**0.048**	1.000 (1.000–1.000)	0.245
ICU admission	**2.573 (1.168–5.666)**	**0.019**	1.839 (0.607–5.568)	0.281
LOS	1.014 (0.983–1.045)	0.394	0.984 (0.928–1.043)	0.581

Bold values indicate statistical significance ($P < 0.05$).

BMI, body mass index; OP, operation; D-lami, decompressive laminectomy; PLIF, posterior lumbar interbody fusion; PLF, posterolateral fusion; DLIF, direct lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; Cr, creatinine; ASA, American Society of Anesthesiologists; CXR, chest simple radiography; EKG, electrocardiogram; DM, diabetes mellitus; CVA, cerebrovascular accident; HTN, hypertension; tbc, tuberculosis; ICU, intensive care unit; LOS, length of stay.

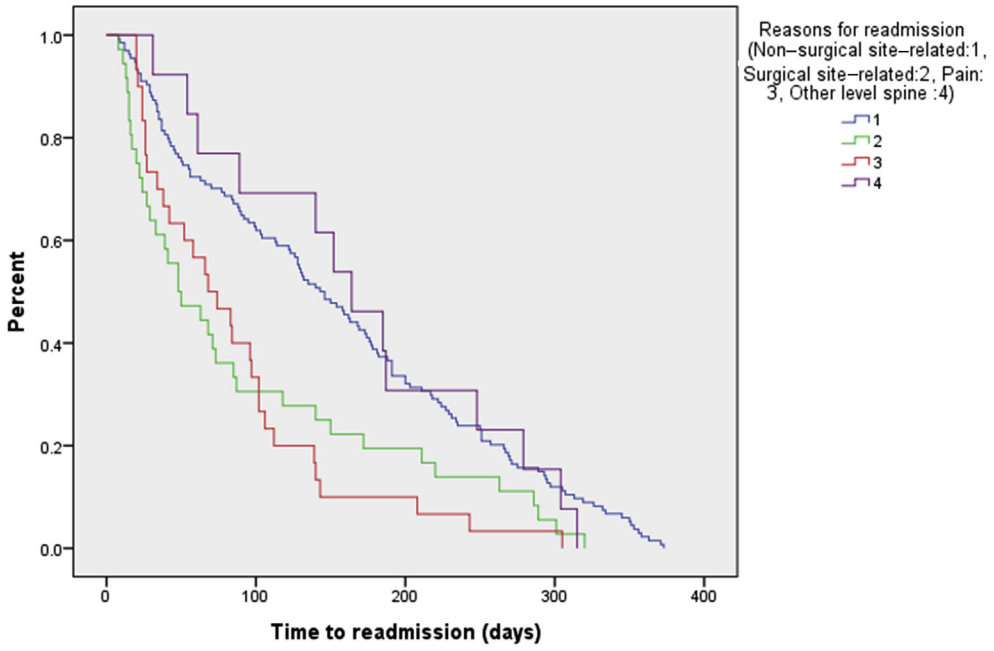

Figure 4. Kaplan-Meier curve of hospital readmission within 360 days after spine surgery showing different median times for the different reasons.

results should be generalized very carefully. However, it is more accurate than the existing nationwide administrative data studies using Current Procedural Terminology or *International Classification of Diseases* codes. Third, as has already been shown in the previous literature, readmission rates have been reported to be often dependent on patients' chronic illness status, socioeconomic status, mental status, and insurance status.[14,15,23-25] However, these factors were not analyzed in this study. Fourth, in this study, we tried to compare results with existing readmission studies as much as possible. However, because of the heterogeneity of the studies, a direct comparative analysis was difficult.

CONCLUSIONS

We found that EKG abnormalities, male sex, low hemoglobin levels, asthma, heart disease, ICU admission, low alanine aminotransferase level, high BMI, and high platelet level were risk factors for readmission. As the postoperative observational period became longer, the reasons for readmission tended to be more related to non-surgical site—related problems than to surgical-related problems. Careful attention and treatment are needed for patients with over >70 years of age when planning surgery.

Table 4. Kaplan-Meier Analysis for Time to Readmission

		95% Confidence Interval (Median)	
Reason for Readmission	**Median Time (days)**	**Lower**	**Upper**
Surgical site related	48.00	15.66	80.34
Pain	68.00	34.45	101.55
Non-surgical site—related	143.00	115.45	170.55
Other level spine	164.00	111.16	216.85

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