Surgical Outcomes and Fusion Rate Following Spine Fusion Surgeries in Patients with Chronic Kidney Disease: *According to Kidney Function*

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Research Article

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Abstract

PURPOSE. To evaluate the surgical outcomes and fusion rate following lumbar fusion surgeries in patients with chronic kidney disease (CKD) according to kidney function.

METHODS. From March 2017 to February 2021, 54 consecutive adult patients with CKD who underwent spine fusion surgery were enrolled. According to the glomerular filtration rate (GFR) categories, 35 patients were classified into the non-end-stage renal disease (ESRD) group (GFR categories 3a–4, eGFR 15–59 mL/min/1.73 m²) and 19 patients into the ESRD group (GFR category 5, eGFR <15 mL/min/1.73 m²).

RESULTS. Baseline characteristics did not differ between the groups. The mean number of fused vertebrae (4.9 ± 2.3 vs. 4.1 ± 2.0 , $p = 0.122$), operative time (228.4 ± 129.6 min vs. 160.5 ± 87.5 min, $p = 0.113$), and surgical bleeding (743.1 ± 630.5 mL vs. 539.5 ± 384.4 mL, $p = 0.354$) did not differ between the groups. The rates of medical complications (25.7% vs. 52.6%, $p = 0.048$) and 3-month readmission (8.6% vs. 35.3%, $p = 0.045$) were significantly different between the groups. The 3-month mortality tended to be higher in the ESRD group (10.5%) than which in the non-ESRD group (2.9%), but the difference was not statistically significant ($p = 0.280$). The rate of pseudarthrosis was significantly higher in the ESRD group (35.3%) than in the non-ESRD group (9.1%, $p = 0.047$).

CONCLUSIONS. Surgeons should be aware of the high morbidity and the pseudarthrosis when considering spine surgeries in patients with ESRD.

Introduction

Chronic kidney disease (CKD) is a progressive condition characterized by structural and functional changes to the kidneys present for at least 3 months ¹. The global burden of CKD is growing substantially, and approximately 10% of adults suffer from some form of CKD ^{2,3}. The number of patients with CKD who underwent spine surgeries has also increased due to new medications, advanced hemodialysis techniques, and kidney transplantation ⁴.

Previous studies have reported increased morbidity and mortality in patients with CKD following spine surgeries ^{4–10}. However, there are few studies regarding bone union following spine fusion surgeries ^{4,11}, despite the fact that the kidneys and skeleton have an intimate biological relationship that can affect bone strength and metabolism ^{12,13}. Ho et al. reported a somewhat higher pseudarthrosis rate of approximately 40% in patients with end-stage renal disease (ESRD) following posterolateral fusion or interbody fusion ¹¹; however, they did not assess the fusion rate according to kidney function.

We hypothesized that patients with CKD were associated with a lower fusion rate as well as increased postoperative morbidity and mortality. The purpose of this study was to evaluate the surgical outcomes

and fusion rate following lumbar fusion surgeries in CKD patients according to kidney function based on the glomerular filtration rate (GFR).

Methods

All methods were carried out in accordance with relevant guidelines and regulations. This study was approved by the institutional review board in Kyung Hee University Hospital at Gangdong (KHNC 2021-09-022) including waiver of informed consent. We retrospectively reviewed the medical records of adult patients with CKD who underwent spine fusion surgeries at a single academic hospital from March 2017 to February 2021. Patients who underwent simple decompression, discectomy, or local procedures were excluded from this study. Patients who were lost to follow-up within six months following surgery were also excluded. CKD was defined as abnormalities of kidney structure or function, present for >3 months, and determined by an estimated GFR (eGFR) $<60 \text{ mL/min/1.73 m}^2$ (GFR categories G3a–G5) ¹⁴. Based on the GFR categories, 54 patients were evaluated in this study. Among them, 35 patients were classified into the non-ESRD group (GFR categories 3a–4, eGFR $15\text{--}59 \text{ mL/min/1.73 m}^2$) and 19 patients to the ESRD group (GFR category 5, eGFR $<15 \text{ mL/min/1.73 m}^2$). None of the patients in the non-ESRD group received hemodialysis (HD) or peritoneal dialysis (PD). In the ESRD group, 18 of 19 patients underwent dialysis (17 patients on HD, one patient on PD). One patient in the group did not initiate dialysis. The medical records and radiographic findings of enrolled patients were reviewed, and comorbidities, medications, laboratory findings, surgical parameters, perioperative course, clinical outcomes, and complications were evaluated. Additionally, a 3-month readmission (from any cause) and 3-month mortality after discharge were also investigated. Perioperative complications were divided into operative complications (complications directly related surgical procedure such as dural tear, wound problem, and neurological deficit), medical complications (medical illness not directly related to the surgical procedures), and mechanical complications (complications related to instrument failure, such as screw pullout or loosening, loss of correction, cage subsidence, and junctional problem). Fusion was assessed using computed tomography (CT) and radiography. Fusion on CT was defined as evidence of trabecular bone bridging between the vertebral bodies. Fusion on the radiograph was defined as less than 5° of angular motion on flexion and extension radiographs or where radiolucency lines, which exceed 50% of the upper or lower surface of the implant, with a width of more than 2 mm, did not appear ^{15,16}.

Results

Baseline Characteristics

The baseline characteristics of CKD patients are summarized in Table 1. The mean age (73.7 ± 9.4 vs. 70.7 ± 8.7 , $p = 0.250$) and sex (male:female = 18:17 vs. 10:9, $p = 0.933$) did not differ between the groups. The mean follow-up period also did not differ between the group (16.8 ± 10.5 vs. 12.3 ± 9.2 , $p = 0.130$). The mean body mass index in the non-ESRD group was greater than that in the ESRD group ($25.8 \pm 3.9 \text{ kg/m}^2$ vs. $23.0 \pm 3.7 \text{ kg/m}^2$, $p = 0.023$). Comorbidities such as hypertension (82.9% vs. 78.9%, $p = 0.728$),

diabetes mellitus (57.1% vs. 57.9%, $p = 0.957$), coronary artery disease (25.7% vs. 15.8%, $p = 0.506$), cerebrovascular disease (17.1% vs. 10.5%, $p = 0.698$), and use of antiplatelet medications (51.4% vs. 47.4%, $p = 0.776$) did not differ between the groups. Forty patients (74.1%) were examined for bone mineral density (BMD) measured by dual energy X-ray absorptiometry preoperatively, and the mean T-scores were lower in patients in the ESRD group (-2.9 ± 1.3) than in the non-ESRD group (-1.9 ± 1.11 , $p = 0.020$). However, there was no significant difference in the proportion of osteoporosis between the groups (34.6% vs. 50.0%, $p = 0.343$). Regarding laboratory findings, the mean preoperative values of blood urea nitrogen (27.0 ± 8.8 mg/dL vs. 53.4 ± 17.7 mg/dL, $p < 0.001$), creatinine (1.5 ± 0.4 mg/dL vs. 7.2 ± 2.8 mg/dL, $p < 0.001$), eGFR (44.0 ± 10.6 mL/min/1.73 m² vs. 8.4 ± 3.5 mL/min/1.73 m², $p < 0.001$), and hemoglobin (11.6 ± 1.8 g/dL vs. 10.5 ± 1.7 g/dL, $p = 0.047$) showed significant differences between the groups. The mean preoperative potassium level did not differ between the groups (4.4 ± 0.5 mEq/L vs. 4.5 ± 0.8 mEq/L, $p = 0.594$).

Table 1
Baseline characteristics of patients with chronic kidney disease

	Non-ESRD (n = 35)	ESRD (n = 19)	p Value
Age (years)	73.7 ± 9.4	70.7 ± 8.7	0.250
Sex	18:17	10:9	0.933
BMI (kg/m ²)	25.8 ± 3.9	23.0 ± 3.7	0.023
Follow-up period (months)	16.8 ± 10.5	12.3 ± 9.2	0.130
Antiplatelet medication (%)	18/35 (51.4%)	9/19 (47.4%)	0.776
HTN (%)	29/35 (82.9%)	15/19 (78.9%)	0.728
DM (%)	20/35 (57.1%)	11/19 (57.9%)	0.957
CAD (%)	9/35 (25.7%)	3/19 (15.8%)	0.506
CVA (%)	6/35 (17.1%)	2/19 (10.5%)	0.698
Osteoporosis (%)	9/26 (34.6%)	7/14 (50.0%)	0.343
BMD (T-score)	-1.9 ± 1.1	-2.9 ± 1.3	0.020
Previous operation (%)	13/35 (37.1%)	3/19 (15.8%)	0.101
BUN (mg/dL)	27.0 ± 8.8	53.4 ± 17.7	0.000
Cr (mg/dL)	1.5 ± 0.4	7.2 ± 2.8	0.000
eGFR (mL/min/1.73 m ²)	44.0 ± 10.6	8.4 ± 3.5	0.000
Hemoglobin (g/dL)	11.6 ± 1.8	10.5 ± 1.7	0.047
Potassium (mEq/L)	4.4 ± 0.5	4.5 ± 0.8	0.594
ESRD: end-stage renal disease; BMI: body mass index; HTN: hypertension; DM: diabetes mellitus; CAD: coronary artery disease; CVA: cerebrovascular disease; BMD: bone mineral density; BUN: blood urea nitrogen; Cr: creatinine; eGFR: estimated glomerular filtration rate			

Perioperative Characteristics

The most commonly operated segments were the lumbar spine (12 patients in the non-ESRD group, eight patients in the ESRD group) and thoracolumbar spine (nine patients in the non-ESRD group, four patients in the ESRD group) spine in both groups (Table 2). The mean number of fused vertebrae (4.9 ± 2.3 vs. 4.1 ± 2.0 , $p = 0.122$), operative time (228.4 ± 129.6 min vs. 160.5 ± 87.5 min, $p = 0.113$), and surgical bleeding (743.1 ± 630.5 mL vs. 539.5 ± 384.4 mL, $p = 0.354$) were greater in the non-ESRD group than those in the

ESRD group; however, this did not reach statistical significance. The proportions of interbody fusion (62.9% vs. 63.2%, $p = 0.983$) and staged operation (31.4% vs. 31.2%, $p = 0.991$) did not differ between the groups. The proportion of postoperative admission to the intensity care unit (ICU) tended to be higher in the non-ESRD group (11.4%) than in the ESRD group (31.6%) without statistical significance ($p = 0.139$). However, the mean length of the hospital stay was significantly longer in the ESRD group (29.6 ± 29.6 days), than in the non-ESRD group (17.1 ± 15.6 , $p = 0.047$). The mode of discharge was significantly different between groups. The rates of discharge to home were significantly lower in the ESRD group (26.3%) than in the ESRD group (71.4%, $p = 0.001$).

Table 2
Perioperative characteristics of patients with chronic kidney disease

	Non-ESRD (n = 35)	ESRD (n = 19)	p Value
Number of fused vertebrae	4.9 $\pm$ 2.3	4.1 $\pm$ 2.0	0.122
Interbody fusion (%)	22/35 (62.9%)	12/19 (63.2%)	0.983
Staged operation (%)	11/35 (31.4%)	6/19 (31.6%)	0.991
Operation time (min)	228.4 $\pm$ 129.6	160.5 $\pm$ 87.5	0.113
Surgical bleeding (mL)	743.1 $\pm$ 630.5	539.5 $\pm$ 384.4	0.354
Level			
Cervical	4	2	
Cervicothoracic	1	1	
Thoracic	2	0	
Thoracolumbar	9	4	
Thoracolumbosacral	2	2	
Lumbar	12	8	
Lumbosacral	5	2	
ICU admission (%)	4/35 (11.4%)	6/19 (31.6%)	0.139
Hospital stay (days)	17.1 $\pm$ 15.6	29.6 $\pm$ 29.6	0.047
Discharge to home (%)	25/35 (71.4%)	5/19 (26.3%)	0.001
ESRD: end-stage renal disease; ICU: intensive care unit			

Complications and Outcomes

Perioperative complications and outcomes are summarized in Table 3 and the Supplementary Table. There were five operative complications in the non-ESRD group (dural tear in three patients and wound dehiscence in one patient) and two in the ESRD group (dural tear in one patient, wound dehiscence in three patients). The rate of operative complications did not differ between the groups (11.4% vs. 21.1%, $p = 0.431$). Approximately half (52.6%) of patients in the ESRD group experienced postoperative medical complications, which were significantly greater than those in the non-ESRD group (25.7%, $p = 0.048$). The most common medical complications were delirium (three patients in the non-ESRD group and five patients in the ESRD group), followed by urinary problems (four patients in the non-ESRD group). Three patients (two patients in the non-ESRD group, one patient in the ESRD group) suffered from acute deterioration of kidney function, and one of them (in the ESRD group) required initiation of hemodialysis. The 3-month readmission rate was significantly higher in the ESRD group (35.3%), than in the non-ESRD group (8.6%, $p = 0.045$). There were three cases of death within 3 months postoperatively. One patient in the non-ESRD group underwent sudden cardiac arrest immediately after the operation, and died within a week despite resuscitation. In the ESRD group, one patient suffered from status epilepticus associated with uremic encephalopathy and died within 3 months. Another patient died from an unknown cause within 2 months of discharge. The 3-month mortality rate tended to be higher in the ESRD group (10.5%) than in the non-ESRD group (2.9%); however, the difference was not statistically significant ($p = 0.280$).

Table 3
Perioperative complications and outcomes of patients with chronic kidney disease

	Non-ESRD (n = 35)	ESRD (n = 19)	p Value
Operative complication (%)	4/35 (11.4%)	4/19 (21.1%)	0.431
Medical complication (%)	9/35 (25.7%)	10/19 (52.6%)	0.048
3-month readmission (%)	3/35 (8.6%)	6/17 (35.3%)	0.045
3-month death (%)	1/35 (2.9%)	2/19 (10.5%)	0.280
Mechanical complication (%)	18/33 (54.5%)	9/17 (52.9%)	0.914
Pseudarthrosis (%)	3/33 (9.1%)	6/17 (35.3%)	0.047
Reoperation (%)	3/33 (9.1%)	0 (0%)	0.542
ESRD: end-stage renal disease			

Approximately half of the patients experienced mechanical complications in both groups postoperatively. The most common mechanical complications were screw loosening (16 patients in the non-ESRD group and seven patients in the ESRD group), followed by cage subsidence (seven patients in the non-ESRD group, three patients in the ESRD group). The rate of mechanical complications did not differ between the groups (54.5% vs. 52.9%, $p = 0.914$). Pseudarthrosis occurred in three patients (9.1%) and six patients (35.3%) in the non-ESRD group and the ESRD group, respectively. The rate of pseudarthrosis was significantly higher in the ESRD group than in the non-ESRD group ($p = 0.047$). The reoperation rate did

not differ between the groups (8.3% vs. 0%, $p = 0.542$). There were three cases of reoperation due to mechanical complications, all of which were in the non-ESRD group. A patient refused revision surgery for mechanical complications in the ESRD group. The rate of revision surgery did not differ between the groups (9.1% vs. 0%, $p = 0.542$).

Discussion

In the present study, we evaluated the surgical outcomes and fusion rates following spine fusion surgeries in patients with CKD according to the severity of kidney function. As expected, the ESRD group demonstrated significantly worse outcomes regarding the length of hospital stay, discharge rate to home, medical complications, 3-month readmission, and pseudarthrosis, as compared to those in the non-ESRD group. Other parameters including the ICU admission rate, operative complications, and 3-month mortality did not reach statistical significance, although the ESRD group showed worse outcomes than those in the non-ESRD group.

There are ample studies regarding surgical outcomes in patients with CKD in various surgical fields. Cloyd et al. evaluated the impact of CKD and ESRD on outcomes following major abdominal surgeries¹⁷. They reported that 30-day mortality (12.8% vs. 1.8%, $p < 0.0001$) and overall complications (23.5% vs. 12.3%, $p < 0.0001$) were significantly higher in the HD group than in the non-HD group based on the National Surgical Quality Improvement Program database. They also found that even moderate CKD (GFR categories 3a, eGFR 30-59 mL/min/1.73 m²) was associated with increased postoperative mortality. Renal impairment has also been demonstrated to increase mortality and postoperative complications following cardiac surgeries^{18,19}. Other researchers reported that CKD resulted in increased postoperative morbidity in orthopedic joint replacement surgeries²⁰⁻²².

Several studies have reported the outcomes of patients with CKD following spinal surgeries. Among them, the majority of studies focused on perioperative mortality and morbidity in CKD patients⁴⁻¹⁰. Nyam et al. reported that in-hospital mortality was significantly higher in ESRD patients than in non-ESRD patients (10.17% vs. 1.39%) following spinal surgeries⁸. Yoshihara et al. also demonstrated that patients with CKD and dialysis had significantly higher risks of in-hospital morbidity and mortality than those without CKD following spinal fusion surgeries in a nationwide database study¹⁰. In the present study, ESRD patients were associated with significantly higher perioperative medical complications (52.6%), which is consistent with previous studies. Moreover, ESRD patients were prone to increased length of hospital stay, possibility of transfer to other medical facilities, and possibility of readmission, compared to non-ESRD patients.

Meanwhile, studies regarding the success rate of bony union following spinal fusion surgeries are scarce. Han et al. noted three out of seven (42.9%) ESRD patients suffered from pseudarthrosis following fusion surgeries in a case series of 12 patients. Ho et al. compared the fusion rates between posterolateral fusion and interbody fusion in 79 patients with ESRD on HD. Although both posterolateral fusion and interbody fusion resulted in similar fusion rates and clinical improvements, the rate of pseudarthrosis

was approximately 40% in both groups ¹¹. These results were also true for the present study that ESRD patients demonstrated significant higher rate of pseudarthrosis (35.3%) than non-ESRD patients (9.1%).

The exact mechanism of defective bony fusion in patients with CKD following spine surgery has not been documented yet. However, it is well-known that CKD has adverse effects on the skeletal system, including disruptions in mineral metabolism, bone microarchitecture, and increased risk of fractures ²³. Such changes occur early in the course of CKD and worsen with the progression of renal impairment ²³. Moreover, CKD patients may have a significant co-prevalence of osteoporosis, although the utility of BMD is undetermined in the later stages of CKD ²³⁻²⁵. Altered bone growth and remodeling processes resulting from combinations of metabolic abnormalities and impairment of bone quality could explain the defective bony fusion in CKD patients following spine surgeries in this study.

The strength of this study was that we conducted a detailed evaluation and comparison of fusion rates between early CKD patients and late CKD (ESRD) patients, in addition to evaluating the clinical outcomes following spine fusion surgeries. Therefore, patients should be informed about the high rate of pseudarthrosis and morbidity following surgery.

The limitations of this study should be noted. First, this study was retrospective in nature, with a relatively short-term follow-up period. Because of the poor general condition associated with CKD, some patients could not make regular follow-ups despite requests for a visit. Second, we classified the patients into dichotomous fashion, rather than the degree of CKD stage. This was because of the small number of patients in this study (there were only five patients with GFR category 4). Therefore, future research with a larger number of patients is necessary to validate this study.

Conclusions

Among CKD patients, ESRD patients were associated with worse outcomes regarding postoperative medical complications, length of hospital stay, and 3-month readmission than those in non-ESRD patients. The pseudarthrosis rate was also significantly higher in ESRD patients than in non-ESRD patients. Surgeons should be aware of the high morbidity and the possibility of pseudarthrosis when considering spine surgeries in patients with ESRD.

Declarations

Acknowledgements: none

Authors' contribution

H.Y.C.: Conceptualization of the study, Performing the experiments, Analysis and interpretation of data, Writing the manuscript; D.J.J.: interpretation of data, Review of the manuscript.

Competing interests: The authors declare no competing interests.

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