INTERNATIONAL JOURNAL of SPINE SURGERY

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Int J Spine Surg published online 5 November 2024
https://www.ijssurgery.com/content/early/2024/11/04/8681

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The International Journal of Spine Surgery
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International Journal of Spine Surgery, Vol. 00, No. 0, 2024, pp. 1–6
https://doi.org/10.14444/8681
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Radiological Spinopelvic Parameters Can Be Risk Factors for Early Total Hip Replacement After Spine Fusion

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ABSTRACT

Background: Interest in the correlation between the spinopelvic complex and its radiographic parameters in early total hip arthroplasty has been increasing. This study investigated whether radiological spinopelvic parameters are risk factors for early total hip replacement (THR) within 1 year of spinal fusion surgery. The primary research question focused on identifying specific spinopelvic changes that may lead to early THR.

Methods: We retrospectively analyzed patients who underwent lumbar spinal fusion between 2016 and 2021. The patients were divided into 2 groups: patients who underwent early THR ($n = 35$) and patients who did not ($n = 213$). Spinopelvic parameters, including pelvic incidence (PI), sacral slope (SS), pelvic tilt, lumbar lordosis, thoracolumbar kyphosis (TLK), sagittal vertical axis, and thoracic kyphosis (TK), were measured before and after surgery. The statistical analyses included inverse probability of treatment weighting, independent *t* tests, χ^2 tests, and logistic regression analyses.

Results: A total of 248 patients were included in the study. The pre- and postoperative TLK and TK angles were significantly smaller in the early THR group than in the late THR group. Increases in the PI and SS after surgery were significant risk factors. The use of interbody fusion techniques was associated with a higher rate of early THR. The difference in the PI minus lumbar lordosis before and after surgery was also significantly correlated with early THR.

Conclusions: Abnormal spinopelvic parameters, especially reduced TLK and TK angles and increased PI and SS, are risk factors for early THR.

Clinical Relevance: Changes in spinopelvic parameters can lead to rapid hip joint destruction, which highlights the need for careful preoperative evaluation and postoperative monitoring of patients to prevent early THR.

Level of Evidence: 3.

Lumbar Spine

Keywords: hip joint, spine fusion, risk factors, spinopelvic, total hip replacement

INTRODUCTION

Various surgical treatments for patients with spinal disorders are considered when conservative treatment is ineffective. Although symptom improvement is expected with only posterior decompression in patients with spinal stenosis or disc herniation at the lumbar spine, there are many cases where posterior spinal fusion is necessary. Spinal fusion is a surgical method that can relieve symptoms and improve activity in patients with spinal stenosis and lumbar spondylosis.[1] However, spinal fusion surgery reduces the range of motion and mobility, causing increased loading on the adjacent segment of the spine. For this reason, the rate of adjacent segment degeneration has been reported to be approximately 16.5% within 5 years and 36.1% within 10 years.[2,3] When the pathological abnormal sagittal alignment of the spine is corrected through spinal fusion, it may change the spinopelvic biomechanics, affecting not only the global sagittal alignment of the spine but also the hip joint. Recent studies have shown that degenerative changes with joint space narrowing at the hip joint occur rapidly in patients who have undergone multiple levels of spinal fusion.[4,5] Interest in the correlation between the spinopelvic complex and its radiographic parameters in early total hip arthroplasty has been increasing. Several recent studies have reported that spinopelvic parameters in sagittal alignment are important influencing factors that can vary depending on whether total hip arthroplasty is performed, which is because the hip joint, pelvis, and spine interact with each other and adapt to the relationship of the kinematic chain when changing posture or walking.[6,7] For these reasons, we sought to analyze the correlation between the 2 surgeries in patients who underwent total hip arthroplasty along with spinal fusion surgery.

We focused on spinopelvic parameters before and after spinal fusion surgery, and the effects that these changes may have on the hip joints. We focused on cases

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wherein hip joint problems suddenly occurred within 1 year of spine surgery. We sought to analyze whether abnormal spinopelvic parameters in patients without existing hip pathology cause early total hip replacement (THR) and whether changes in spinopelvic parameters before and after spinal surgery could lead to early THR.

METHODS

Patient Selection

This retrospective study included patients who underwent lumbar spinal fusion at our hospital between 2016 and 2021. The inclusion criteria were as follows: patients who underwent lumbar interbody and posterolateral fusion; patients with surgical levels from L1 to S1; patients without hip pathology at the time of spinal surgery; and patients with normal findings in the preoperative plain hip radiography. Patients with preoperative hip osteoarthritis of grade 2 or higher, preexistent hip pain, history of femur fracture, or hip or arthroplasty cases were excluded from the study to create a uniform condition. In particular, among patients using long-term steroids, patients with avascular necrosis of femoral head findings on preoperative radiography were excluded to reduce analysis bias. Various spinopelvic parameters and other risk factors for early THR within 1 year after spinal surgery were compared between the 2 groups. This study was approved by the Institutional Review Board of our institution (IRB number: 3-2024-0139). The requirement for informed consent was waived due to the retrospective nature of the study.

Evaluated Factors

Two skilled orthopedic surgeons measured the parameters together and reported the average value. The intraclass coefficient was also calculated and found to be reliable, with a value of 0.98. The parameters were measured using standing whole-spine lateral x-ray images obtained within 1 month before and after surgery using the PACS system (GE Centricity PACS GE AW Server 3.2). The spinopelvic parameters that we measured were the pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), thoracolumbar kyphosis (TLK), sagittal vertical axis, thoracic kyphosis (TK), and PI minus LL (PI–LL). The spinopelvic parameters were measured as follows: We drew a vertical line from the center of the femoral head and another line from the femoral head to the center of the midpoint of the sacral upper endplate. The angle between the 2 lines was recorded as the PT. The SS was the angle between the sacral upper endplate and the horizontal line. The PI was calculated by adding the PT and SS. The LL was the angle between the upper endplates of L1 and S1. The TK was the angle between the T5 upper endplate and T12 lower endplate, and the TLK was the angle between the T10 upper endplate and L2 lower endplate, which implied a thoracolumbar junction. The sagittal vertical axis was defined as the sagittal offset of the vertical line from the C7 center of the body, called the C7 plumb line, from the posterior tip of the sacral upper endplate. The PI–LL, which indicates the optimal degree of correction, was calculated by subtracting LL from PI.[6,8,9] The reason for measuring the pre- and postoperative spinopelvic parameters is that, usually, surgical correction goals are almost similar. Thus, we considered it important to calculate the difference in pre- and postoperative spinopelvic parameters to determine the impact on early total hip arthroplasty. The demographic data on steroid use, current alcohol consumption, preoperative hemoglobin level, and dyslipidemia, including triglycerides, which are known risk factors for destructive hip arthritis, were collected and compared.[10]

Statistical Analysis

Statistical analysis was performed using SAS (version 9.4; SAS Institute, Cary, NC, USA) and R statistics (version 4.2.2). It is very rare for patients who have undergone spinal fusion to undergo early total hip arthroplasty. The inverse probability of treatment weighting (IPTW) was used to control the difference in prevalence between the early THR group and the group without early THR.[11,12] Specifically, in order to statistically correct and balance this small probability, IPTW was used to adjust for the confusion identified in this study. In addition, independent *t* tests, χ^2 tests, and logistic regression were used for the analysis. Statistical significance was set at $P < 0.05$, and 95% confidence intervals were used.

RESULTS

Demographics

A total of 248 patients who underwent spinal fusion surgery at the lumbar spine level were included in this study; 35 patients underwent early THR within 1 year of spine surgery, and 213 patients did not undergo early THR. The average age of the patients who underwent early THR was 69.1 years, of which 10 (28.6%) were men and 25 (71.4%) were women. The average age of the patients who did not undergo early THR was 68.9 years, of whom 86 (40.4%) were men and 127 (59.6%)

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Table 1. Patient demographic data with inverse probability of treatment weighting.

Variables	Weighted Mean (SE) or Weighted N (%) Early THR = 0 (n = 215.5)	Early THR = 1 (n = 47.2)	P
Age, y	68.9 (0.6)	67.9 (1.5)	
Gender			0.541
Woman (0)	132.7 (61.6)	28.7 (60.7)	0.9332
Man (1)	82.8 (38.4)	18.6 (39.3)	
Preoperative TG, mg/dL	148.5 (3.3)	170.9 (6.9)	0.0035
Preoperative Hgb, mg/dL	13.0 (0.1)	12.5 (0.3)	0.0815
Preoperative Hct, %	38.3 (0.6)	37.4 (0.8)	0.3882
BMI	25.4 (0.3)	24.5 (0.6)	0.1774
No. of surgical levels treated			
1	133.4 (61.9)	28.6 (60.6)	0.9983
2	70.3 (32.6)	16.0 (33.9)	
3	8.7 (4.1)	2.0 (4.2)	
4	3.1 (1.4)	0.6 (1.3)	
Preoperative smoking			
No (0)	199.2 (92.4)	45.7 (96.8)	0.3765
Yes (1)	16.3 (7.6)	1.5 (3.2)	
Preoperative alcohol use			
No (0)	185.0 (85.8)	32.9 (69.6)	0.0435
Yes (1)	30.5 (14.2)	14.4 (30.4)	
Preoperative steroid use			
No (0)	205.4 (95.3)	35.3 (74.9)	0.0007
Yes (1)	10.2 (4.7)	11.9 (25.2)	
Osteoporosis			
No (0)	149.4 (69.3)	12.4 (26.2)	<0.0001
Yes (1)	66.1 (30.7)	34.9 (73.8)	

Abbreviations: THR, total hip replacement; TG, triglyceride; Hgb, hemoglobin; Hct, hematocrit; BMI, body mass index.

were women. The number of levels operated varied from 1 to 4. IPTW was performed, and demographic data are presented in Table 1. The age, sex, number of surgeries, and body mass index were not statistically different between the 2 groups.

Radiological Parameters

According to the independent variable analysis, the preoperative and postoperative TLK and TK angles were significantly different between the 2 groups. The mean weighted values of the preoperative TLK in the early and nonearly THR groups were 7.4° and 20.8°, respectively. The degree of TLK was significantly lower in the early THR group than in the nonearly THR group ($P < 0.0001$). Similarly, the mean postoperative TLK angle in the early THR group was 7.5°, and the mean postoperative TLK angle in the nonearly THR group was 20.1°. The postoperative TLK angle was significantly lower in the early THR group than in the nonearly THR group ($P < 0.0001$). The pre- and postoperative TK angles were similar. However, the preoperative TK angles in the early and nonearly THR groups were significantly different ($P = 0.0213$). Similarly, the postoperative TK angles in the early and nonearly THR groups were significantly different ($P < 0.001$).

Table 2. Independent variable analysis with inverse probability of treatment weighting.

Variables	Weighted Mean (SE) or Weighted N (%) Early THR = 0 (n = 215.5)	Early THR = 1 (n = 47.2)	P
Preoperative			
PI	55.2 (0.9)	51.1 (2.0)	0.0644
SS	32.3 (0.6)	29.6 (2.3)	0.2472
PT	22.9 (0.7)	21.6 (2.4)	0.5901
LL	35.2 (1.0)	38.9 (3.5)	0.3012
TLK	20.8 (0.10)	7.4 (1.1)	<0.0001
SVA	55.1 (2.10)	68.1 (10.2)	0.217
TK	21.8 (0.8)	17.5 (1.7)	0.0213
PI–LL	20.0 (1.1)	12.2 (4.1)	0.0661
Postoperative			
PI	55.0 (0.8)	55.1 (2.4)	0.964
SS	32.2 (0.7)	34.2 (2.3)	0.4072
PT	22.8 (0.7)	21.0 (2.1)	0.4164
LL	36.9 (1.0)	37.4 (3.6)	0.9048
TLK	20.1 (1.0)	7.5 (1.2)	<0.0001
SVA	45.9 (2.7)	51.2 (5.1)	0.3579
TK	22.3 (0.9)	15.0 (1.6)	<0.0001
PI–LL	18.1 (1.0)	17.7 (3.8)	0.9336
Difference (△)			
△ PI	−0.19 (0.7)	3.98 (1.10)	0.0463
△ SS	−0.09 (0.6)	4.60 (2.2)	0.0434
△ PT	−0.13 (0.5)	−0.62 (1.7)	0.7774
△ LL	1.76 (0.8)	−1.53 (1.9)	0.1141
△ TLK	−0.81 (0.6)	0.09 (0.7)	0.3451
△ SVA	−9.24 (2.10)	−16.92 (10.6)	0.4816
△ TK	0.44 (0.6)	−2.53 (1.8)	0.1253
△ PI–LL	−1.94 (0.9)	5.50 (2.7)	0.0094
Fusion type			
Posterolateral fusion	144.9 (67.2)	21.1 (44.6)	0.0199
Interbody fusion	70.7 (32.8)	26.1 (55.4)	
Blood fusion			
No (0)	195.5 (90.7)	36.9 (78.9)	0.079
Yes (1)	20.0 (9.3)	10.3 (21.9)	

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PI–LL, pelvic incidence minus lumbar lordosis; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; THR, total hip replacement; TK, thoracic kyphosis; TLK, thoracolumbar kyphosis.
Note: △ indicates the difference between the post- and preoperative values.

The pre- and postoperative TK angles were smaller in the early THR group than in the nonearly THR group (Table 2).

The differences in the TK and TLK angles between the pre- and postoperative values were very small because we only included lumbar spine fusion cases in this study. There was no significant difference in the change in (△) TLK and △TK angle between the early and nonearly THR groups. However, the △PI and △SS before and after the surgery were statistically different between the early and nonearly THR groups ($P = 0.0463$ and $P = 0.0434$, respectively). The mean values of PI and SS were corrected more approximately and increased by 3.9° and 4.5°, respectively, in the early THR group. Furthermore, the difference between △PI–LL was 5.5° and −1.9° in the early and nonearly THR groups, respectively, and was significantly different between the 2 groups ($P = 0.0094$).

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Table 3. Logistic regression with inverse probability of treatment weighting.

	Univariable	
Variables	**OR (95% CI)**	***P***
Preoperative		
PI	0.975 (0.950–1.000)	0.0492
SS	0.975 (0.945–1.005)	0.0952
PT	0.989 (0.960–1.018)	0.4503
LL	1.016 (0.995–1.037)	0.134
TLK	0.884 (0.844–0.926)	< 0.0001
SVA	1.006 (1.000–1.014)	0.0679
TK	0.968 (0.940–0.996)	0.0255
PI–LL	0.974 (0.955–0.993)	0.0065
Postoperative		
PI	1.001 (0.976–1.026)	0.9549
SS	1.018 (0.987–1.050)	0.2567
PT	0.983 (0.953–1.014)	0.2849
LL	1.002 (0.982–1.022)	0.8605
TLK	0.894 (0.854–0.935)	<0.0001
SVA	1.004 (0.996–1.012)	0.3904
TK	0.946 (0.917–0.975)	0.0004
PI–LL	0.999 (0.979–1.019)	0.9004
Difference (△)		
△ PI	1.037 (1.007–1.067)	0.0152
△ SS	1.045 (1.014–1.078)	0.0046
△ PT	0.992 (0.953–1.033)	0.6946
△ LL	0.976 (0.950–1.003)	0.086
△ TLK	1.015 (0.974–1.057)	0.4805
△ SVA	0.996 (0.989–1.003)	0.2817
△ TK	0.966 (0.933–0.999)	0.0461
△ PI–LL	1.040 (1.016–1.065)	0.0009
Fusion type		
Posterolateral fusion	Ref	0.0043
Interbody fusion	2.544 (1.341–4.827)	
Blood fusion		
No (0)	Ref	0.0173
Yes (1)	2.737 (1.195–6.270)	

Abbreviations: CI, confidence interval; LL, lumbar lordosis;OR, odds ratio; PI, pelvic incidence; PI–LL, pelvic incidence minus lumbar lordosis; PT, pelvic tilt; Ref, reference; SS, sacral slope; SVA, sagittal vertical axis; TK, thoracic kyphosis; TLK, thoracolumbar kyphosis.
Note: △ indicates the difference between the postoperative and preoperative values.

The patients who underwent the interbody fusion technique also had a significantly higher rate of early THR ($P = 0.0199$).

The △TK and △TLK angles significantly affected early THR after spinal surgery, wherein a decrease in the angle increases the possibility of early THR after surgery ($P < 0.05$). In the logistic regression analysis, the △PI–LL was all statistically significant, wherein a decrease in the preoperative PI–LL value increased the possibility of early THR ($P < 0.05$, OR: 1.040). As the increase in the △PI and △SS between pre- and postoperative values became larger, the possibility of performing early THR increased ($P < 0.05$, OR: 1.037; $P < 0.05$, OR: 1.045, respectively). One of the distinctive features of logistic regression was that interbody fusion was associated with a higher incidence of early THR after spinal fusion surgery. The odds ratio when using the interbody was 2.544, which indicated a higher chance of early THR after spine surgery (Table 3).

DISCUSSION

Several studies have reported a deep interaction between the pathophysiology of the hip joint and the spine, suggesting that presurgical sagittal spinal deformity and abnormal spinopelvic mobility are factors that can cause instability in patients who underwent total hip arthroplasty.[4,7,8,13] In addition, Buckland et al reported that only 59% of patients who underwent total hip arthroplasty had normal lumbar alignment, indicating that abnormal sagittal spinopelvic alignment is common.[14–16] Spinal fusion surgery can cause changes in several spinopelvic parameters, including the LL and TK,[17] and the effect of these changes on the planning of the operation and postoperative clinical outcomes of total hip arthroplasty is becoming more important. One study reported that a postoperative increase in PT reduces the coverage of the femoral head, and the resulting stress concentration may ultimately cause rapid destructive hip coxopathy.[18] However, there is no clear consensus on the exact sequential relationships or definite mechanisms of this event.

The complex relationship between spinopelvic parameters and compensatory mechanisms of the spine and lower extremities has received increasing attention, and many studies have reported a relationship between these factors. The current study showed the overall characteristics of spinopelvic parameters before and after surgery and tried to identify the factors that affect rapid hip joint destruction, which leads to early THR.[19] The first characteristic found in this study was that the TK and TLK angles affect early THR occurrence. When the TK and TLK angles decreased, the possibility of early THR increased. The mean pre- and postoperative TK values were 17.5% and 15.0%, respectively, which were within the normal range. Therefore, if the TK angle loses its normal kyphotic status, it could easily affect the hip joint biomechanical status. Maintaining a normal TK angle is important for preventing rapid hip joint destruction. In the early THR group, there was a difference between the PI and SS before and after spinal fusion surgery, which increased after surgery; however, there was no significant difference in the PT before and after surgery. A commonly accepted formula is PI = SS + PT; thus, it can be interpreted that as the SS increased, the PI also increased. The change in SS and PI after surgery caused changes in the anteversion and slope of the hip joint, which led to the early THR. Considering the reasons for early THR in cases of spinal fusion using interbody fusion, the modification in disc height is easier in the case of interbody fusion than in posterolateral spinal fusion, which easily causes loading changes to the hip joint.

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The results of this study confirmed a correlation between the pre- and postoperative values of several spinopelvic parameters and early total hip arthroplasty. However, there were limitations in analyzing more complex correlations and influences between these spinopelvic parameters. In addition, the failure to conduct analysis due to the lack of a simple and clear evaluation method for neuromuscular functional factors for each patient is considered a shortcoming. To account for this, we analyzed body mass index, which was judged to be meaningful as there was no significant difference between the 2 groups.

Another limitation of this study is that the causes of early THR were not accurately analyzed. Various assumptions have been made regarding this phenomenon. The cause of early THR may be hip pathology caused by an abnormal gait due to pelvic parameters or neurological findings due to spinal stenosis. In addition, sarcopenia that may occur after surgery may cause hip pathology. Various other assumptions can be made; however, in this study, only the impact based on radiological findings was analyzed, and it is necessary to analyze the differences according to more specific causes in follow-up studies.

CONCLUSION

According to our study, the TK and TLK values have a strong effect on the hip joint, which induces hip joint destruction that requires early THR. A postoperative increase in the PI and SS values and the use of an interbody cage for spinal fusion could act as risk factors for hip joint destruction and early THR. However, further studies are needed to analyze the complex mechanism and correlation between parameters to clearly elucidate this mechanism.

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Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

Ethics: This study was approved by the Institutional Review Board of our institution (IRB number: 3-2024-0139). The requirement for informed consent was waived due to the retrospective nature of the study.

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