ORIGINAL ARTICLE

Adjacent segment disease on hip joint as a complication of spinal fusion surgery including sacroiliac joint fixation

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Abstract

Purpose Recently, the number of adult spinal deformity surgeries including sacroiliac joint fixation (SIJF) by using an S2 alar iliac screw or iliac screw has increased to avoid the distal junctional failure. However, we occasionally experienced patients who suffered from hip pain after a long instrumented spinal fusion. We hypothesized that long spinal fusion surgery including SIJF influenced the hip joint as an adjacent joint. The aim of this paper was to evaluate the association between spinal deformity surgery including SIJF and radiographic progression of hip osteoarthritis (OA).

Methods This study was retrospective cohort study. In total, 118 patients who underwent spinal fusion surgery at single center from January 2013 to August 2018 were included. We measured joint space width (JSW) at central space of the hip joint. We defined reduction of more than 0.5 mm/year in JSW as hip OA progression. The patients were divided into two groups depending on either a progression of hip osteoarthritis (Group *P*), or no progression (Group *N*).

Results The number of patients in Group P and Group N was 47 and 71, respectively. Factor that was statistically significant for hip OA was SIJF ($p = 0.0065$, odds ratio = 7.1, 95% confidence interval = 1.6–31.6). There were no other significant differences by the multiple logistic regression analysis.

Conclusion This study identified spinal fixation surgery that includes SIJF as a predictor for radiographic progression of hip OA over 12 months. We should pay attention to hip joint lesions after adult spinal deformity surgery, including SIJF.

Keywords Adult spinal deformity surgery · Sacroiliac joint fixation · Hip osteoarthritis · Adjacent joint pathology

Introduction

The number of spinal fusion surgeries for adult spinal deformities continues to increase in an aging society [1]. We often perform fusions of the sacrum to avoid sagittal decompensation and distal junctional failure after long instrumented spinal fusions [2]. However, we experienced patients who suffered from hip pain after a long instrumented spinal fusion. There is one report that described the relation between postoperative hip pain and adult spinal deformity surgery [3].

A major complication observed in adult spinal deformity surgery is adjacent segment disease (ASD). The development of ASD is problematic because it can necessitate further surgical intervention and can adversely affect functional outcomes [4]. The occurrence rates of radiographic and symptomatic ASD have been reported to be 26.6 and 8.5%, respectively [4]. The relationship between ASD and spinal fusion surgery has been frequently discussed. The risk factors of ASD were reported to be age, genetic factors, high body mass index, pre-existing adjacent segment degeneration, laminectomy at the adjacent level of fusion, excessive distraction of the fusion level, insufficient lumbar lordosis, multilevel fixation, floating fusion, coronal wedging of L5-S disc, pelvic tilt, and osteoporosis [4].

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ASD has been reported to develop not only in spinal segments but also in the sacroiliac joint. It has been reported that lumbosacral fusions can induce sacroiliac joint pain postoperatively [5, 6]. It was revealed that a lumbosacral fusion increased stress at the sacroiliac joint [7]. Thus, fusion surgeries may increase mechanical stress at the adjacent part whether it is a spinal segment or a joint.

Recently, the number of adult spinal deformity surgeries including sacroiliac joint fixation (SIJF) by using an S2 alar iliac (SAI) screw or iliac screw has exhibited a significant increase, because the rate of aging in the general population has increased [2]. We hypothesized that adult spinal deformity surgery including SIJF by using a SAI screw or iliac screw influenced the hip joint as an adjacent joint. However, the relation between SIJF and hip joint lesions has not been reported. The purpose of this study was to evaluate the association between spinal deformity surgery including SIJF and radiographic progression of hip osteoarthritis (OA).

Patients and methods

Patients

In this retrospective study, 118 patients who underwent spinal fusion surgery from January 2013 to August 2018 were included. All patients provided informed consent prior to surgery, and the study protocol was approved by the institutional ethical committee of Wakayama Medical University. The inclusion criterion was that patients underwent spinal fixation surgery for adult spinal deformity or lumbar canal stenosis of more than four vertebrae. The exclusion criteria were as follows: (1) a history of previous hip surgeries (e.g., osteotomy, arthroplasty) and (2) patients with a baseline joint space width (JSW) of less than 0.5 mm. All participants provided informed consent before the operation. The patients were divided into 2 groups depending on either a progression of hip osteoarthritis (Group P), or no progression (Group N). The number of patients in Group P and Group N was 47 and 71, respectively.

Radiographic assessment

A digital standing anteroposterior whole-spine radiograph including hip joint was obtained in a standardized manner by the same skilled techniques. The patients were asked to stand comfortably while placing their hands on cheeks and facing front. We evaluated the radiographic images obtained within 1 month after the operation and 12 months after as the second-line evaluation to minimize the influence of pelvic rotation and tilt. To adjust the scale of two radiographs, we measured tear drop distance and adjusted the scale of the radiograph taken as follows to the baseline. From the

radiograph, a single orthopedic doctor measured JSW to assess degeneration. The JSW was measured at three locations: in the lateral space of the subchondral sclerotic line, at the apical transection of the weight-bearing surface by a vertical line through the center of femoral head, and in the medial space of the weight-bearing surface bordering on the fovea, in 0.1 mm increments from an image magnified four times [8] (Fig. 1). The interclass correlation of each radiographic measurement for randomly selected radiographs of 30 hips was 0.68, 0.86, and 0.39 at lateral, center, and medial locations, respectively. Therefore, we decided to measure and compare JSW at only the central space. We defined reduction of more than 0.5 mm/year in JSW as hip OA progression from past reports [8]. At the same time, the sacral slope was measured for adjusting the influence of the pelvic position on the JSW in the statistics.

Statistical analysis

JMP Pro 14.1 (SAS Institute Inc., Cary, NC, USA) was used for all analysis. We compared data between the 2 groups using univariable regression analysis. The Chi-square test was used to compare categorical data, and the Student t test was used to compare continuous parameters. Logistic regression analysis was performed to determine predictive factors for the narrowing of HJW. A multiple regression analysis was performed to determine the predictive factors of the narrowing of the JSW (mm). A multiple logistic regression analysis was performed to determine the predictive factors of hip OA progression. The explanatory variables included age, sex, body mass index (BMI), change in sacral slope between 1 month and 1 year after surgery, the number of fusion segments, and the presence or absence of SIJF in both multivariate models. We confirmed that no multicollinearity existed between the explanatory variables by calculating the variance inflation factor (VIF). However, we used propensity score adjustment to avoid overfitting in the logistic model. The propensity score was created from age, sex, and BMI into a single variable. A p-value < 0.05 was considered statistically significant.

Results

A total of 118 eligible patients were enrolled in this study, including 28 males and 90 females. The average age was 70.5 years old. The average BMI was 23.3 (kg/m^2). HJW was 4.2 mm at pre-operation, and 3.8 mm 1 year after the operation, and the narrowing of JSW was 0.43 mm. The number of patients with a narrowing of JSW of more than 0.5 mm was 47. The number of fixation segments was 8.1 and the number of patients with SIJF was 64 (Table 1). The multiple regression analysis revealed that the change

Table 1 Characteristics of the study participants

Number of participants	118
Age (years, mean ± SD)	70.5 ± 6.8
Men/female	28/90
Body mass index (kg/m², mean ± SD)	23.3 ± 3.1
SS within 1 month after operation (degree, mean ± SD)	27.3 ± 7.3
SS at 1 year after operation (degree, mean ± SD)	26.2 ± 7.5
Change in SS within 1 month after operation and 1 year after operation (degree, mean ± SD)	1.5 ± 2.1
JSW within 1 month after operation (mm, mean ± SD)	4.2 ± 0.89
JSW at 1 year after operation (mm, mean ± SD)	3.8 ± 0.94
Change in JSW within 1 month after operation and 1 year after operation (mm, mean ± SD)	0.43 ± 0.30
Number of the patients with narrowing of JSW ≧ 0.5 mm	47 (39.8%)
Number of fixation segments (segments, mean ± SD)	8.1 ± 3.5
Number of the patients with fixation of SI joint	64 (54.2%)

SD Standard deviation, *SS* Sacral slope, *JSW* Joint space width, *SI* Sacroiliac

Table 2 Factors associated with the narrowing of JSW after long fusion surgery (multiple regression analysis)

	p value	Standardized *β*	VIF
Age, years	0.52	0.05	1.04
Men/women	0.28	0.1	1.23
Body mass index	0.21	0.1	1.04
JSW within 1 month after the operation	0.52	0.06	1.1
Number of fixation segments	0.6	−0.08	3.09
Fixation of SI joint	**0.0006**	0.52	3.06
Change in SS within 1 month after operation and 1 year after operation	0.8	−0.02	1.02

Bold values denote statistical significance at the *p* < 0.05 level

VIF Variance inflation factor, *JSW* joint space width, *SI* sacroiliac, *SS* sacral slope

in JSW was significantly associated with whether SIJF was performed ($p = 0.0006$; standardized $\beta = 0.52$). The other parameters did not show significant associations (Table 2). We performed nonparametric analysis between Group P and Group N. There were significant differences in sex, number of fixation segments, and ratio of the patients in whom SIJF was performed. The mean age in Group N was higher than in Group P, but the difference was not significant. No significant differences were observed in BMI and SS (Table 3). Multiple logistic regression analysis showed that there was a significant difference in SIJF ($p = 0.0065$,

odds ratio = 7.1, 95% CI = 1.6–31.6). There were no other significant differences (Table 4).

Representative case

A 58-year-old female patient presented low back pain. Her BMI was 21.6 (kg/m²). She underwent spinal fusion surgery from the L2 to the ilium. JSW at the right hip at 1 month after the operation was 4.7 mm, and tea drop distance was 131.6 mm. She underwent spinal fusion surgery from L2 to the ilium (Fig. 2, left). JSW 1 year after the operation was 3.6 mm, and tear drop distance was 133.1 mm. JSW 1 year after the operation was adjusted for 3.5 mm by the tear drop distance. The narrowing of JSW was 1.2 mm (Fig. 2, right). The patient experienced pain in the right hip and underwent drug therapy.

Discussion

This study identified spinal fixation surgery that includes SIJF as a predictor for radiographic progression of hip OA over 12 months. This is the first study to suggest an association between SIJF as the lower end of fusion and radiographic progression of hip OA.

Degeneration that develops at mobile segments above or below a fused spinal segment is known as ASD [4], which develops not only in the mobile segments, but also in joints adjacent to the spinal fusion site. It has been reported that lumbosacral fusion induced sacroiliac joint pain [7]. Sacroiliac joint dysfunction in patients who had undergone spine surgeries in the past was detected by single photon emission computed tomography and bone scintigraphy [6]. The results showed significantly increased uptake in sacroiliac joints, which reflect mechanical overloading and sacroiliitis. The finite element study also revealed that lumbar fusion leads to an increase in the angular motion at the sacroiliac joint [9]. The sacroiliac joint plays a key role in both load transfer and stability. It acts to transfer upper body weight through the pelvis and down into the lower extremities [10, 11]. Numerous clinical and experimental studies of ASD after lumbar fusion procedures showed increased mobility in the proximal and distal adjacent segments and increased stress on the facet and disk of adjacent mobile segments [12]. The following changes were due to a transfer of motion from the fused segment to the next mobile intact segments [13].

Similarly, hip joint pain after spinal surgery has been reported [3]. This finding was controversial, and it was unclear whether sacroiliac fixation in long spinal instrumented surgery impacted hip lesion [14]. We investigated and clarified the association between SIJF and progression of hip joint lesions. It has been reported that hip motion is accompanied by spinal mobility during daily activities [15]

Table 3 Comparison between the progression group (Group P) and the non-progression group (Group N)

	Group P (47 patients)	Group N (71 patients)	p value
Age (years)	69.5 ± 7.5	72.1 ± 5.4	0.08
Men/women	6/41	22/49	**0.02**
Body mass index (kg/m^2)	23.0 ± 3.0	23.4 ± 3.2	0.64
Number of fixation segments	9.4 ± 3.4	7.3 ± 3.4	**0.0012**
Fixation of the sacroiliac joints	37 (78.7%)	27 (38.0%)	**< 0.0001**
C7 sagittal vertical axis within 1 month after the operation (mm)	34.3 ± 34.2	37.1 ± 37.9	0.68
SS within 1 month after the operation (degree)	26.3 ± 7.8	28.1 ± 6.9	0.19
SS at 1 year after the operation (degree)	24.9 ± 8.8	27.1 ± 6.5	0.14
Change in SS within 1 month after operation and 1 year after operation	1.5 ± 2.6	1.5 ± 1.7	0.57
JSW within 1 month after operation (mm)	4.1 ± 1.0	4.2 ± 0.8	0.21
JSW at 1 year after operation (mm)	3.4 ± 1.0	4.0 ± 0.8	**0.0002**
Change in JSW within 1 month after operation and 1 year after operation (mm)	0.7 ± 0.2	0.2 ± 0.1	**< 0.0001**

The progression was defined as the reduction of joint space width more than 0.5 mm/year.

Bold values denote statistical significance at the $p < 0.05$ level

BMI Body mass index, *JSW* Joint space width, *SI* sacroiliac, *SS* sacral slope

Table 4 Factors associated with the hip OA progression after long fusion surgery (multiple logistic regression analysis)

	Odds ratio	95% CI	p value
Propensity score (age, sex, body mass index)	0.03	0.00–0.70	**0.03**
Number of fixation segments (+ 1 segment)	1.05	0.85–1.30	0.64
Fixation of SI joint (1 = not fixed)	7.1	1.60–31.6	**0.0065**
Change in SS within 1 month after operation and 1 year after operation (+ 1 degree)	1.04	0.86–1.24	0.67

We defined reduction of more than 0.5 mm/year in JSW as hip osteoarthritis progression. The propensity score was created from age, sex, and body mass index into a single variable to avoid overfitting in the logistic model

Bold values denote statistical significance at the $p < 0.05$ level

OA osteoarthritis, *CI* confidence interval, *SI* sacroiliac, *SS* sacral slope
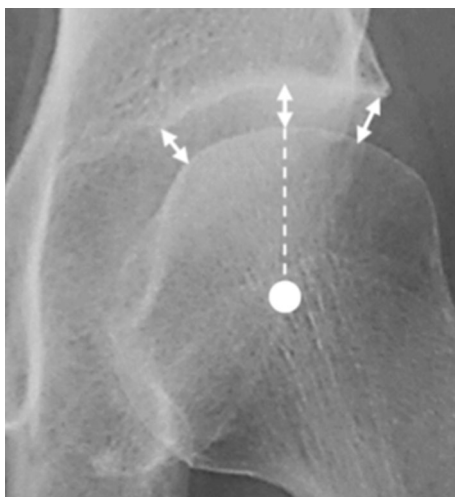
Fig. 1 The joint space width was measured at 3 locations: the lateral space of the subchondral sclerotic line, apical transection of weight-bearing surface by a vertical line through the center of femoral head, and medial space of the weight-bearing surface bordering on the fovea [8]

and that lower mobility of the thoracolumbar level is associated with progression of hip OA [16]. It was also revealed that the contribution of hip motion relative to that of the lumbar spine motion was increased during the sit-to-stand and stand-to-sit motions in patients with low back pain [15]. Moreover, during stand-to-sit, patients with stiff spines due to degenerative disk disease experienced less spinal flexion and more hip flexion, which consequently potentially increased the risk of impingement of the acetabular rim on the proximal femur [17]. It was reported that contact pressure of the hip joint with femoroacetabular impingement was increased and was associated with hip osteoarthritis [18]. Therefore, less spinal mobility can be a risk factor for hip OA progression through the potential increase in mechanical load on the hip. Spinal fusion from the lower thoracic to the sacroiliac joint decreased spinal motion, which was compensated by hip motion. Therefore, spinal fusion surgery can also be a risk factor for hip OA progression through the potential increase in mechanical load on the hip.

Fig. 2 A 58-year-old female. Preoperative JSW at the right hip was 4.7 mm, and the tea drop distance was 131.6 mm. JSW 1 year postoperatively was 3.6 mm, and the tea drop distance was 133.1 mm. HJW 1 year postoperatively was adjusted for 3.5 mm by the tear drop distance. The narrowing of HJW was 1.2 mm

In this study, the progression of hip joint lesions was evaluated with radiography. The JSW was often measured at three locations—the lateral, central, and medial locations. If the minimum JSW was found aside from the three locations in the weight-bearing area, JSW of the narrowest point was also recorded as a fourth measurement. Minimum JSW was defined as the smallest of three or four measurements [8]. We conducted an intraclass correlation of each radiographic measurement between two orthopedic surgeons, which was consistent only in central locations. This is the reason that the patients included in this study were much older than past reports [19, 20] and had characteristics of osteoarthritis such as osteophytes and lateral roofs. However, we believe this is not a major concern because it was reported that the contact pressure for cartilage of acetabulum and femoral head mainly occurs in the central areas of the acetabulum and at the top of the femoral head [21]. Radiographic progression of the hip OA has been previously defined as a reduction of more than 0.5 mm in JSW [8], and natural reduction of JSW was defined as 0.2–0.3 mm/year in JSW [22]. In this study, 78.7% patients underwent adult spinal fusion surgery with SIJF progressed over 0.5 mm. These findings imply the possibility of adding stress onto the hip joint as adjacent joint.

Several limitations to this study should be noted. First, the number of the fusion segments was much larger in Group P than in Group N. Second, the follow-up duration of 12 months was relatively short. Although the yearly mean narrowing of hip joint has been reported as a risk factor for the need for total hip arthroplasty [8], it was not determined whether the progression speed of the hip joint after spinal fusion including SIJF was maintained. We did not use the Kellgren–Lawrence scale because the radiological change of the hip joint was not so drastic within 12 months. A longer follow-up is needed to establish the relationship between the progression of hip OA and adjacent joint disease after spinal fusion.

Second, the study did not clarify the relation between other risk factors for hip osteoarthritis and SIJF. Group P was older than Group N, but there was no significant difference. There were also more women in Group P than in Group N. These are reported as risk factors of hip osteoarthritis [23]. A large number of fusion segments is also thought to increase the risk of ASD, but multi-regression analysis showed no significant difference in this study [4].

The two variables, the number of fusion segments and the fixation of the SI joint, show the variance inflation factors (VIFs) as 3.09 and 3.06, respectively, in the multiple regression analysis (Table 2). A VIF < 4 does not indicate a severe multicollinearity, so sacroiliac joint fixation alone might be recognized as a risk factor, not long spinal fusion. One reason may be that the case series in the present study did not include short-segment fusion because the aim of the operation was ASD correction. Therefore, a larger population study is necessary. Third, we did not evaluate clinical symptoms, including hip pain. In the future, we will report long-term follow-up results, including clinical symptoms, in a larger cohort in the future. In conclusion, this study revealed how differences in the level of LIV influence the hip joint. SAI screw fixation may be a risk factor for radiographic progression of hip OA after surgery. We should pay attention to hip joint lesions after adult spinal deformity surgery, including SIJF. Moreover, we should explain the possibility of the progression of hip lesions to patients. Here, we propose the concept of "adjacent segment disease on hip joint as a complication of spinal fusion surgery, including sacroiliac joint fixation".

Code availability The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest None of the authors have any conflict of interest to declare.

Ethics approval All patients provided informed consent prior to surgery, and the study protocol was approved by the institutional ethical committee of Wakayama Medical University.

Consent to participate All patients provided informed consent prior to surgery.

Consent for publication All patients provided informed consent for publication.

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