Sacroiliac Joint Pain Should Be Suspected in Early Buttock and Groin Pain after Adult Spinal Deformity Surgery: An Observational Study

Shizumasa Murata, Hiroshi Iwasaki, Masanari Takami, Keiji Nagata, Hiroshi Hashizume, Shunji Tsutsui, Ryo Taiji, Takuhei Kozaki and Hiroshi Yamada

Department of Orthopedic Surgery, Wakayama Medical University, Kimiidera, Japan

Abstract:

Introduction: Sacroiliac joint pain (SIJP) is one of the pathological conditions of adjacent segment disorders occurring after adult spinal deformity (ASD) surgery. This study aimed to test the hypothesis that even in ASD surgery using S2 alar-ilial (S2AI) screws, SIJP can develop much earlier than reported previously and can be rescued by ultrasound-guided sacroiliac joint block.

Methods: Overall, 94 patients with ASD treated with long spinal fusion using S2AI screws were prospectively investigated for SIJP postoperatively, and the effect of ultrasound-guided sacroiliac joint block was evaluated. Additionally, the relationship between the symptomatic side of the SIJP and the surgical procedure; the preoperative and postoperative whole-spine sagittal and coronal alignment, lumbar pelvis sagittal plane alignment, and pelvic incidence-lumbar lordosis were retrospectively compared between the groups with and without SIJP.

Results: Eleven of 94 cases (11.7%) developed SIJP. The average onset was 12.0 (±6.2) days after surgery. The “one-finger test,” “Gaenslen test,” and “tenderness of the posterosuperior iliac spine” had high positivity rates for SIJP. Night pain occurred in 81.8% of patients and was one of the diagnostic features. There were no significant relationships between the symptomatic side of SIJP and the approach-side of lumbar interbody fusion, donor site of the iliac bone graft, or malposition of the S2AI screw. There were no significant differences in preoperative characteristics and radiological parameters between the SIJP-positive and -negative groups preoperatively, postoperatively, or in postoperative changes. Two of the 11 cases required the SIJ block four times, but all patients eventually achieved >70% pain relief with no recurrence.

Conclusions: For good pain control and physical therapy, the fact that early buttock-groin pain after spinal fusion surgery has a 12% likelihood of being due to SIJP and can be relieved with the ultrasound-guided SIJ block is clinically important for diagnosis and pain management.

Keywords: Adult spinal deformity, sacroiliac joint pain, S2 alar-iliac screws, ultrasonography, sacroiliac joint block, ultrasound-guided sacroiliac joint block, physical therapy

Introduction

Globally, the average human life expectancy has doubled in the past 200 years. The incidence of musculoskeletal disease, including spinal disorders, is increasing with the growing aging population. Adult spinal deformity (ASD) has gained significant attention in the past decade following improvements in diagnostic tools, classification schemes, and surgical techniques. With advances in minimally invasive surgery, such as extreme lateral interbody fusion (XLIF), older adults or high-risk patients who were previously inoperable can now undergo surgery. Many reports have shown that deformity correction and fixation for ASD generally yield good results.

Lumbar and buttock pain may remain or appear after spinal fusion, making treatment challenging. Failed back surgery syndrome (FBSS) is a term that groups conditions with recurrent lower back pain after spinal surgery, with or with-
out a root component. FBSS reportedly affects 10%-40% of patients after lumbar surgery and 5%-50% patients after spinal fusion surgery. Sacroiliac joint (SIJ) pain (SIJP) has recently been reported as one of the FBSSs and recognized as one of the pathological conditions of adjacent segment disorders. SIJP after spinal fusion reportedly develops six months to one year after surgery. Long spinal fusion surgery has also been reported to increase the incidence of SIJP, which can be reduced by using S2 alar-iliac (S2AI) screws.

However, clinicians have often encountered cases of SIJP after spinal fusion, developed much earlier than previously reported, dramatically reduced by ultrasound-guided SIJ block. Ultrasound can be performed quickly by the bedside, and patients are not exposed to radiation. This allows physicians to safely and accurately perform various medical procedures. Based on these reports, we hypothesized that even in ASD surgery using S2AI screws, SIJP develops much earlier than previously reported and can be rescued by ultrasound-guided SIJ block. This study aimed to test this hypothesis and use the results for postoperative pain control, promotion of physical therapy, and resumption of daily living activities in patients with ASD. To that end, we prospectively investigated the prevalence of SIJP from postoperation to discharge and the effect of ultrasound-guided SIJ block in ASD surgery cases using S2AI. In addition, the relationship between the symptomatic side of SIJP and the surgical procedure; the preoperative and postoperative whole-spine sagittal alignment, whole-spine coronal alignment, and lumbar pelvis sagittal plane alignment were retrospectively compared between the groups with and without SIJP.

Materials and Methods

The study was conducted according to the ethical standards of the Research Ethics Committee of Wakayama Medical University, Wakayama, Japan and the 1964 Helsinki Declaration and its later amendments. Informed consent was obtained from all participants.

Between January 2019 and December 2020, all consecutive patients who had (1) symptomatic ASD and (2) underwent long corrective fusion from the thorax to the pelvis using S2AI screws were enrolled in the study. In all patients in this series, posterior lumbar interbody fusion was performed on L5/S. We defined ASD as a C7 sagittal vertical axis of more than 50 mm and pelvic incidence-lumbar lordosis of more than 10°, in accordance with the Scoliosis Research Society-Schwab classification. The exclusion criteria were as follows: (1) history of spine surgery, (2) bedridden status due to pre-existing problems, (3) current severe infection, or (4) concurrent acute fracture. A total of 98 patients met the initial inclusion criteria. Three patients with histories of lumbar spinal surgery and one with cervical spinal surgery were excluded, leaving 94 patients in the final analysis (Fig. 1).
SIJP diagnostic methods and ultrasound-guided SIJ block

We prospectively investigated postoperative buttock and groin pain after surgery. Causes of postoperative buttock and groin pain were diagnosed on physical, neurological, and imaging findings. If required, additional nerve root blocks, facet blocks, and lumbar discography were performed. Using “A Diagnostic Scoring System for SIJP” (Table 1), patients who scored 4 or higher were diagnosed with SIJP. Then, after explaining the condition to the patient and obtaining consent, an ultrasound-guided SIJ block was performed to treat SIJP. The patient was shifted to the prone position, the surgeon stood on the healthy side, and the ultrasound device was placed on the affected side. The risk of erroneous operation can be reduced by arranging the operator, puncture site, and ultrasonic device to line up in a straight line. To confirm that the needle tip had reached under the posterior sacroiliac ligament, an injection containing 1 mL of 1% lidocaine, 2 mg of betamethasone sodium phosphate, and 3 mL of saline was administered, and pain relief was evaluated using a visual analog scale. Scores were obtained and compared immediately after and 15 minutes after the SIJ block. The injection was considered effective if the patient reported a ≥70% decrease in pain. In addition, ultrasound-guided SIJ blocks were repeated if more than 30% of the pain recurred or if the pain restricted physical therapy.

Clinical outcome measurements

We investigated the sex, age, body mass index (BMI), bone mineral density, type of deformity (kyphosis or kyphoscoliosis), and upper instrumented vertebra of the target patients. For cases with SIJP, the onset date, symptomatic side, night pain, positive rate of each test of “A Diagnostic Scoring System for SIJP,” and number of times the SIJ block was administered were investigated. In addition, the relationship between the symptomatic side of the SIJP and the approach-side of the lumbar interbody fusion (LIF), donor site of iliac bone graft, and malposition of the S2AI screw were compared. Second, the baseline characteristics and postoperative outcomes one month after surgery were compared between the SIJP-positive and SIJP-negative groups. Moreover, risk factors for SIJP were evaluated using logistic regression analyses with the SIJP-negative group as the reference group. Odds ratios (ORs) and 95% confidence intervals, as well as p-values, were calculated. All statistical analyses were performed using JMP Pro version 14 (SAS Inc., Cary, NC, USA), with a significance level of p<0.05.

Results

Characteristics of the SIJP-positive group

The average follow-up period was 16.5±3.5 (10-22) months. The average age of the 94 patients was 72.1 (±4.9) years, and the majority (86.2%) were females. Their average BMI was 23.3 (±2.7) kg/m², and the majority (86.2%) were in the T10-S2 fusion range. Eleven patients were SIJP-positive; only one was male (Table 2). The average onset of SIJP was 12.0 (±6.2) days after surgery, the symptomatic side of SIJP was even on the left and right, and SIJP developed on both sides in two patients (Table 2). The positivity rate of each test of “A Diagnostic Scoring System for SIJP” is shown in Table 2. Apart from the main complaint, “groin pain,” the positive rates for “one-finger test,” “Gaenslen test,” and “tenderness of the posterosuperior iliac spine” were very high at 81.8%. Although not included in the diagnostic criteria, night pain was present in 81.8% of the patients, which is considered a feature of SIJP after spinal fusion (Table 2). The average number of SIJ blocks required to alleviate SIJP was 2.0 (±1.3). Some patients required SIJ
blocks several times owing to pain recurrence within a few days. Two of the 11 patients required SIJ block four times, but in the end, all patients achieved ≥70% decrease in pain without any recurrence. Usually, the pain recurred within a month of surgery during the period of hospitalization; but fortunately, the pain relief persisted during the follow-up period in outpatients (Table 2).

### Table 2. Characteristics of the Sacroiliac Joint Pain-positive Group.

| N=11 |     |
|------|-----|
| Sex (male/female) | 1/10 |
| Age (years) | 71.9±6.4 |
| BMI (kg/m²) | 23.6±2.4 |
| Onset date of SIJP (days) | 12.0±6.2 |
| Symptomatic side of SIJP (n) right/left/bilateral | 4/5/2 |
| Night pain (%) | 81.8 (9/11) |
| SIJP scoring system one-finger test (%) | 81.8 (9/11) |
| groin pain (%) | 100 (11/11) |
| sitting pain (%) | 36.4 (4/7) |
| Gaenslen test (%) | 81.8 (9/11) |
| tenderness of PSIS (%) | 81.8 (9/11) |
| tenderness of STL (%) | 18.2 (2/11) |
| Total (points) | 6.9±0.9 |
| SIJ block once (%) | 54.5 (6/11) |
| twice (%) | 9.1 (1/11) |
| three times (%) | 18.2 (2/11) |
| four times (%) | 18.2 (2/11) |
| Average | 2.0±1.3 |

SIJP: sacroiliac joint pain, BMI: body mass index, PSIS: posterosuperior iliac spine, STL: sacrotuberous ligament. Data are presented as n, %, mean±standard deviation (range), or number

### Relationship between the symptomatic side of SIJP and surgical procedure

We suspected a causal relationship between LIF and SIJP and assessed it by comparing the symptomatic side of the SIJP and the approach side of the LIF. The symptomatic side of the SIJP was divided into the following three groups: “right,” “left,” and “bilateral”; the approach side of the LIF was divided into the following three groups: XLIF into the “right” and “left,” and posterior lumbar interbody fusion into “posterior.” However, no significant association was found between the symptomatic side of the SIJP and the approach side of the LIF (p=0.7496) (Table 3). In all cases, we took the iliac bone graft from the right or left side. Considering the possibility that bone graft donor site pain was misdiagnosed as SIJP, the relationship between the symptomatic side of the SIJP and the donor site of the iliac bone graft was investigated. However, no significant association was observed (p=0.9465) (Table 3). In addition, considering the possibility that implant failure related to the S2AI screw was linked to the SIJP, the malposition of the S2AI screw was evaluated using CT. Malposition of the S2AI screw was observed in one of the 11 cases. In this case, the S2AI screw on the left side was inserted from the left SIJ. No inward or outward deviation or loosening was noted. Since it was only one case and the screw malposition was on the opposite side of the SIJ pain, it was difficult to identify an association (p=0.3819) (Table 3).

### Comparison of the preoperative characteristics between the SIJP-positive and SIJP-negative groups

We suspected a difference in the type of deformity and range of spinal fusion and thus investigated the SIJP-positive and SIJP-negative groups. However, there were no significant differences between the two groups, not only in basic items such as sex, age, BMI, and bone mineral density, but also in the type of deformity and range of spinal fusion (p=0.553, 0.8991, 0.6428, 0.5559, 0.8883, and 0.262, respec-

### Table 3. Relationship Between the Symptomatic Side and Surgical Procedure.

| Approach of LIF (n) | right-SIJP | left-SIJP | bilateral-SIJP | p-value |
|---------------------|------------|-----------|----------------|--------|
| right               | 0          | 1         | 0              | 0.750  |
| left                | 2          | 3         | 1              |        |
| posterior           | 2          | 1         | 1              |        |
| Donor site of bone graft (n) | | | | 0.947 |
| right               | 2          | 2         | 1              |        |
| left                | 2          | 3         | 1              |        |
| Malposition of S2AI (n) | | | | 0.382 |
| none                | 0          | 0         | 0              |        |
| right               | 0          | 0         | 0              |        |
| left                | 1          | 0         | 0              |        |

SIJP: sacroiliac joint pain, LIF: lumbar interbody fusion, S2AI: S2 alar iliac, *: statistically significant, defined as p<0.05. Data are presented as n, %, mean±standard deviation (range), or number
### Table 4. Preoperative Characteristics of the Participants.

|                  | SIJP (−) | SIJP (+) | p     |
|------------------|----------|----------|-------|
| Sex (male/female)| 4/79     | 1/10     | 0.553 |
| Age (years)      | 72.1±4.7 | 71.9±6.4 | 0.958 |
| BMI (kg/m²)      | 23.2±2.8 | 23.6±2.4 | 0.558 |
| BMD (T-score)    | −1.3±1.2 | −1.1±0.9 | 0.345 |
| Deformity kyphosis (%) | 61.5 (51/83) | 63.6 (7/11) | 0.888 |
| kyphoscoliosis (%) | 38.5 (32/83) | 36.4 (4/11) | 0.262 |
| UIV              |          |          |       |
| T8 (%)           | 1.2 (1/83) | 9.1 (1/11) |       |
| T9 (%)           | 4.8 (4/83) | 9.1 (1/11) |       |
| T10 (%)          | 86.8 (72/83) | 81.8 (9/11) |       |
| T11 (%)          | 7.2 (6/83) | 0        |       |

SIJP: sacroiliac joint pain, BMI: body mass index, BMD: bone mineral density, UIV: upper instrumented vertebra, *: statistically significant, defined as p<0.05. Data are presented as n, %, mean±standard deviation (range), or number.

### Table 5. Radiological Comparison Between Sacroiliac Joint Pain-positive and -negative Groups.

|                  | SIJP (−) | SIJP (+) | p     |
|------------------|----------|----------|-------|
| C7 SVA (mm)      |          |          |       |
| pre              | 124.7±53.0 | 125.8±62.4 | 0.944 |
| post             | 36.0±30.4  | 33.9±21.6 | 0.902 |
| change           | 88.7±55.5  | 91.9±55.3 | 0.967 |
| C7PL-CSVL (mm)   |          |          |       |
| pre              | 24.2±11.9  | 13.2±11.9 | 0.162 |
| post             | 20.7±15.5  | 17.8±15.5 | 0.608 |
| change           | 3.5±24.6   | −4.6±13.9 | 0.306 |
| PI (°)           |          |          |       |
| pre              | 50.8±9.7   | 47.1±11.3 | 0.303 |
| post             | 51.0±8.5   | 46.8±9.4  | 0.130 |
| change           | −0.2±1.9   | 0.3±2.4   | 0.938 |
| LL (°)           |          |          |       |
| pre              | 5.2±22.5   | 7.2±19.4  | 0.911 |
| post             | 41.7±8.8   | 38.6±6.7  | 0.371 |
| change           | 36.5±20.7  | 31.4±15.8 | 0.499 |
| PI-LL (°)        |          |          |       |
| pre              | 45.6±20.5  | 39.9±23.3 | 0.646 |
| post             | 9.3±9.1    | 8.3±13.4  | 0.663 |
| change           | 36.4±20.5  | 31.6±16.0 | 0.580 |
| PT (°)           |          |          |       |
| pre              | 41.8±11.9  | 35.5±11.9 | 0.073 |
| post             | 24.4±9.0   | 21.0±12.6 | 0.407 |
| change           | 17.3±11.6  | 14.5±9.0  | 0.484 |
| Malposition of S2AI (+/−) | 3/80 | 1/10 | 0.398 |

SIJP: sacroiliac joint pain, C7PL-CSVL: C7 plumb line-center sacral vertical line, SVA: sagittal vertical axis, PI: pelvic incidence, LL: lumbar lordosis, PI-LL: pelvic incidence-lumbar lordosis, PT: pelvic tilt, S2AI: S2 alar iliac, pre: before surgery, post: one month after surgery, change: change before and after surgery, *: statistically significant, defined as p<0.05. Data are presented as n, %, mean±standard deviation (range), or number.

### Discussion

Some of our patients complained of severe buttock and groin pain approximately two weeks after ASD surgery. This is approximately when the patient can leave the bed voluntarily, and physical therapy becomes more active toward discharge. However, severe buttock and groin pain make it difficult for patients to continue physical therapy and delays recovery of daily living activities. This early postoperative buttock and groin pain (within approximately two weeks of surgery) is often diagnosed as surgical wound pain or donor site pain of the iliac bone graft and left untreated^{18}. This study aimed to demonstrate that in ASD surgery using S2AI screws, SIJP can develop much earlier than previously reported and can be ameliorated by ultrasound-guided SIJ block. In this prospective study, 11 of 94 cases (11.7%) developed SIJP. The average onset date of SIJP was 12.0 (± 6.2) days after surgery. The “one-finger test,” “Gaenslen test,” and “tenderness of the posterosuperior iliac spine” had a high positive rate and were helpful in the diagnosis of SIJP. Although not included in the diagnostic criteria, night pain was found in 81.8% of patients and was one of the di-

---

Note: The original text and tables have been reformatted for clarity and readability, maintaining the original meaning and structure as closely as possible. The tables contain numerical data and statistical comparisons relevant to the study's findings on preoperative characteristics and radiological comparisons between SIJP-positive and -negative groups. The discussion section highlights the early onset of SIJP symptoms, the diagnostic utility of certain tests, and the successful treatment approach using ultrasound-guided SIJ block.
SIJP after spinal fusion to the sacrum reportedly reduces the frequency of adjacent segment disorder. Spinal fusion to the sacrum increases the risk of SIJP as a stress concentrated on the remaining joints. This is attributed to the ability to insert S2AI screws without special attention to the physiological rotation axes such as SIJ nutations and counter-nutations. On the other hand, loosening of the S2AI screw is considered a risk factor for SIJP. This study revealed that SIJP occurs much earlier than previously reported in cases of spinal deformity surgery using S2AI screws. Furthermore, it is clinically significant that SIJP, which occurs when perioperative physical therapy is important, is relieved by ultrasound-guided SIJ block, which can be performed quickly at the bedside, and patients are not exposed to radiation. To date, the reason underlying this condition has not been determined, possibly because of its misdiagnosis as a type of wound pain or donor site pain that cannot be relieved. The SIJP that occurs six months to one year after fixation, as reported so far, is thought to be caused by degenerative changes. However, another pathology should be considered for SIJP occurring early after surgery, which was investigated in this study, because the onset was too early to cause degenerative changes. In this study, the following reasons could be considered the cause of SIJP despite the insertion of the S2AI screw. First, it is possible that the S2AI deviated from the physiological axis of rotation, such as nutations and counter-nutations. Second, the S2AI screw, which penetrates the articular surface of the SIJ, may have damaged the joint and provoked an inflammatory response. The nerves distributed in the SIJ are formed by the lateral branch of the L5 posterior branch and the lateral branch of the posterior branch of S1-S4 on the posterior surface of the pelvis. Third, SIJP may occur due to direct damage to these nerve branches or stimulation associated with a postoperative inflammatory response by regular surgical procedures. In particular, inflammatory reactions may be involved in SIJP in the early postoperative period, as in the latter two instances. In this study, the fact that many cases were accompanied by night pain and relieved with steroid-containing block highlights the involvement of the inflammatory response in SIJP.

Table 6. Factors Associated with Sacroiliac Joint Pain.

| Factor                                      | Odds ratio (95% CI) | p    |
|---------------------------------------------|---------------------|------|
| Sex (female)                                | 0.51 (0.07–10.42)   | 0.583|
| Age (+1 year)                               | 0.99 (0.87–1.13)    | 0.898|
| BMI (+1 kg/m²)                              | 1.05 (0.83–1.31)    | 0.642|
| BMD (+1 T-score)                            | 1.17 (0.68–1.95)    | 0.552|
| Malposition of S2AI (+)                     | 2.67 (0.13–23.24)   | 0.450|
| Change of PT (+1°)                          | 0.98 (0.92–1.03)    | 0.429|
| Change of PI (+1°)                          | 0.81 (0.81–1.47)    | 0.475|
| Change of LL (+1°)                          | 0.99 (0.95–1.02)    | 0.414|
| Change of PI-LL (+1°)                       | 0.99 (0.95–1.02)    | 0.455|
| Change of PT (+1°)                          | 0.98 (0.92–1.03)    | 0.429|
| Change of PI-LL (+1°)                       | 0.99 (0.95–1.02)    | 0.455|
| Change of LL (+1°)                          | 0.99 (0.95–1.02)    | 0.455|
| Change of PI-LL (+1°)                       | 0.99 (0.95–1.02)    | 0.455|
| Change of LL (+1°)                          | 0.99 (0.95–1.02)    | 0.455|
| Number of segments fused (+1 segment)       | 2.88 (0.86–9.77)    | 0.084|
| Change of C7 SVA (+1 mm)                    | 1.00 (0.99–1.01)    | 0.856|
| Change of C7PL-CSVL (+1 mm)                 | 0.99 (0.96–1.01)    | 0.281|
| Change of PI (+1°)                          | 1.11 (0.81–1.47)    | 0.475|
| Change of PT (+1°)                          | 0.98 (0.92–1.03)    | 0.429|
| Deformity (kyphosis)                        | 1.0 (0.31–4.47)     | 0.888|
| Malposition of S2AI (+)                     | 2.67 (0.13–23.24)   | 0.450|

CI: Confidence interval, BMI: body mass index, BMD: bone mineral density, C7PL-CSVL: C7 plumb line-center sacral vertical line, SVA: sagittal vertical axis, PI: pelvic incidence, LL: lumbar lordosis, PI-LL: pelvic incidence-lumbar lordosis, PT: pelvic tilt, S2AI: S2 alar iliac, pre: before surgery, post: one month after surgery, change: change before and after surgery, *: significant defined as p<0.05. Data are presented as number.
Nevertheless, this study had some limitations. First, the incidence of SIJP after spinal fusion was approximately 12%, making it difficult to amass larger cohort sizes in a single-center study. To gather enough data, this study required a retrospective design, which creates some inherent bias; therefore, additional larger scale, multicentric studies are necessary to clarify the pathophysiology of SIJP after spinal fusion. Second, there is the problem of false positives with the response to SIJ blocks as mentioned earlier, SIJP may be associated with an early postoperative inflammatory response, and there may have been a few spontaneously relieved cases. Third, the possibility of SIJ lesions already lurking before surgery cannot be completely ruled out. It is difficult to clarify whether SIJP first developed during surgery.

Finally, we compared the background factors and spinal parameters before and after surgery between the groups with and without SIJP; however, we could not point out a clear cause of SIJP. We speculate that the cause of SIJP is direct damage to nerve branches and joints due to the screw or inflammatory reaction of the SIJ; however, there are few reports to support this, and further research is needed. Moreover, risk factors for SIJP were evaluated using logistic regression analysis with the SIJP-negative group as the reference group. The number of segments fused was the most associated with SIJP among various factors, though it was not a statistically significant parameter.

Therefore, for good pain control and physical therapy, the fact that early buttock-groin pain after spinal fusion surgery has a 12% likelihood of being due to SIJP and can be relieved with ultrasound-guided SIJ block is clinically vital information for diagnosis and pain management.

**Disclaimer:** Hiroshi Hashizume is one of the editors of this journal. This author was not involved in the editorial evaluation or decision for this article.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

**Sources of Funding:** None.

**Acknowledgement:** The authors wish to thank Prof. Fumihiro Tajima for his supervise. We also thank Ms. Maya Ueda for her medical writers.

**Author Contributions:** H.I. and S.M. designed the study; M.T., R.T., K.N., and T.K. performed the experiments and analyzed the data; H.H. and S.T. provided critical reagents; H.Y. supervised the experiments; S.M. wrote the manuscript.

**Ethical Approval:** The study was conducted in accordance with the ethical standards of the Research Ethics Committee of Wakayama Medical University (approval number: 3247) and the 1964 Helsinki Declaration and its later amendments.

**Informed Consent:** Informed consent was obtained from all participants.

**References**

1. Oppey J, Vaupel JW. Demography. Broken limits to life expectancy. Science. 2002;296(5570):1029-31.
2. Smith JS, Shaffrey CI, Ames CP, et al. Treatment of adult thoro- 
columbar spinal deformity: past, present, and future. J Neurosurg Spine. 2019;30(5):551-67.
3. Ozgur BM, Aryan HE, Pimenta L, et al. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar inter-body fusion. Spine J. 2006;6(4):435-43.
4. Kelly MP, Lurie JD, Yanik EL, et al. Operative versus nonopera- 
tive treatment for adult symptomatic lumbar scoliosis. J Bone Joint Surg Am. 2019;101(4):338-32.
5. Smith JS, Lafage V, Shaffrey CI, et al. Outcomes of operative and nonoperative treatment for adult spinal deformity: a prospective, multicenter, propensity-matched cohort assessment with minimum 2-year follow-up. Neurosurgery. 2016;78(6):851-61.
6. Murata S, Hashizume H, Nagata K, et al. Kitchen elbow sign predicts surgical outcomes in adults with spinal deformity: a retro- 
spective cohort study. Sci Rep. 2021;11(1):12859.
7. North RB, Campbell JN, James CS, et al. Failed back surgery syn- 
drome: 5-year follow-up in 102 patients undergoing repeated op-
eration. Neurosurgery. 1991;28(5):685-90; discussion 90-1.
8. Baber Z, Erdek MA. Failed back surgery syndrome: current per-
spectives. J Pain Res. 2016;9:979-87.
9. Daniell JR, Osti OL. Failed back surgery syndrome: a review arti-
cle. Asian Spine J. 2018;12(2):372-9.
10. Shapiro CM. The failed back surgery syndrome: pitfalls surround-
ing evaluation and treatment. Phys Med Rehabil Clin N Am. 2014; 
25(2):319-40.
11. Ivanov AA, Kiapour A, Ebraheim NA, et al. Lumbar fusion leads to increases in angular motion and stress across sacroiliac joint: a finite element study. Spine. 2009;34(5):E162-9.
12. Liliang PC, Lu K, Liang CL, et al. Sacroiliac joint pain after lumb- 
ar and lumbosacral fusion: findings using dual sacroiliac joint blocks. Pain Med. 2011;12(4):565-70.
13. Yoshihara H. Sacroiliac joint pain after lumbar/lumbosacral fusion: current knowledge. Eur Spine J. 2012;21(9):1788-96.
14. Heini PF. Reviewer’s comment concerning “The percutaneous stabilization of the sacroiliac joint with hollow modular anchorage screws: a prospective outcome study.” Eur Spine J. 2013;22(10): 
2325-31.
15. Unoki E, Abe E, Murai H, et al. Fusion of multiple segments can increase the incidence of sacroiliac joint pain after lumbar or lumb- 
osacral fusion. Spine. 2016;41:999-1005.
16. Unoki E, Miyakoshi N, Abe E, et al. Sacroepileptic fixation with s2 alar iliac screws may prevent sacroiliac joint pain after multise- 
gment spinal fusion. Spine. 2019;44;1024-30.
17. Unoki E, Miyakoshi N, Abe E, et al. Sacroiliac joint pain after multiple-segment lumbar fusion: a long-term observational study- 
non-fused sacrum vs. fused sacrum. Spine Surg Relat Res. 2017;1 
(2):90-5.
18. DePalma MJ, Ketchum JM, Saullo TR. Etiology of chronic low 
back pain in patients having undergone lumbar fusion. Pain Med. 
2011;12(5):732-9.
19. Murakami E, Kurosawa D, Aizawa T. Treatment strategy for sac-
roiliac joint-related pain at or around the posterior superior iliac spine. Clin Neurol Neurosurg. 2018;165:43-6.
20. Murata S, Iwasaki H, Natsumi Y, et al. Vascular evaluation around 
the cervical nerve roots during ultrasound-guided cervical nerve
root block. Spine Surg Relat Res. 2020;4(1):18-22.
21. Schwab F, Patel A, Ungar B, et al. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. Spine. 2010;35(25):2224-31.
22. Kurosawa D, Murakami E, Ozawa H, et al. A diagnostic scoring system for sacroiliac joint pain originating from the posterior ligament. Pain Med. 2017;18(2):228-38.
23. Murakami E, Tanaka Y, Aizawa T, et al. Effect of periarticular and intraarticular lidocaine injections for sacroiliac joint pain: prospective comparative study. J Orthop Sci. 2007;12(3):274-80.
24. Nagata H, Schendel MJ, Transfeldt EE, et al. The effects of immobilization of long segments of the spine on the adjacent and distal facet force and lumbosacral motion. Spine. 1993;18(16):2471-9.
25. Ha KY, Lee JS, Kim KW. Degeneration of sacroiliac joint after instrumented lumbar or lumbosacral fusion: a prospective cohort study over five-year follow-up. Spine. 2008;33:1192-8.
26. Shen FH, Mason JR, Shimer AL, et al. Pelvic fixation for adult scoliosis. Eur Spine J. 2013;22(Suppl 2):S265-75.
27. Tonosu J, Kurosawa D, Nishi T, et al. The association between sacroiliac joint-related pain following lumbar spine surgery and spinopelvic parameters: a prospective multicenter study. Eur Spine J. 2019;28(7):1603-9.
28. Nanda A, Manghwani J, Kluger PJ. Sacropelvic fixation techniques—Current update. J Clin Orthop Trauma. 2020;11(5):853-62.
29. Menger R, Park PJ, Bixby EC, et al. Complications in ambulatory pediatric patients with nonidiopathic spinal deformity undergoing fusion to the pelvis using the sacral-alar-iliac technique within 2 years of surgery. J Neurosurg Pediatr [Internet]. 2021 Apr;28(1):28-33. Available from: https://thejns.org/pediatrics/view/journals/j-neurosurg-pediatri28/1/article-p13.xml
30. Burns CB, Dua K, Trasolini NA, et al. Biomechanical comparison of spinopelvic fixation constructs: iliac screw versus S2-alar-iliac Screw. Spine Deform. 2016;4(1):10-5.
31. Bernard Jr TN, Kirkaldy-Willis WH. Recognizing specific characteristics of nonspecific low back pain. Clin Orthop Relat Res. 1987;217:266-80.
32. Tonosu J, Oka H, Watanabe K, et al. Characteristics of the spinopelvic parameters of patients with sacroiliac joint pain. Sci Rep. 2021;11(1):5189.
33. Hart FD, Taylor RT, Huskisson EC. Pain at night. Lancet. 1970;1(7652):881-4.