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Sacroiliac Joint Ankylosis in Pelvic Ring Injuries with Posterior Ilium Fractures

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Purpose: Sacroiliac joint (SIJ) changes due to ankylosis may influence the fracture pattern of the posterior ilium, an essential component of the posterior ring. This study aimed to assess the association between SIJ ankylosis and posterior ilium fractures (PL) in pelvic ring injuries.

Materials and Methods: A retrospective analysis was conducted on 272 patients diagnosed with pelvic ring injuries between January 2004 and October 2023. Patients were categorized into non-ankylosed (n=185) and ankylosed (n=87) SIJ cohorts. The prevalence of SIJ ankylosis in our study sample was 32.0% (87/272). Patient demographics, SIJ ankylosis, PL, and fracture classification using computed tomography were compared between the two groups. PL was defined as any type of posterior ring injury with fracture lines extending to the region posterior to the iliac pillar, with or without SIJ subluxation or dislocation. To determine the association between SIJ ankylosis and PL, a logistic regression analysis adjusted for age, body mass index, sex, and energy of injury mechanism was performed.

Results: Our results found that the ankylosed group had a higher PL ratio (47.1% vs. 31.4%, P=0.012), was older (64.9 years vs. 53.5 years, P<0.001), and included more males (58.6% vs. 37.8%, P=0.001) than the non-ankylosed group. Multivariate analysis revealed a significant association between SIJ ankylosis and PL (odds ratio 2.15, P=0.022).

Conclusion: This study determined that SIJ ankylosis is significantly associated with PL in pelvic ring injuries; transformed SIJ may contribute to changes in posterior ring fracture patterns.

Keywords: Pelvic ring injury, Sacroiliac joint ankylosis, Fracture classification, Posterior ilium

INTRODUCTION

Types of pelvic ring injuries are determined by the magnitude and direction of the forces applied to the pelvis, which influence ring stability and fracture pattern characteristics. Currently, two main pelvic ring fracture classification systems are widely accepted. The classification system described by Tile[1] has been adopted by the Association for the Study of Internal Fixation (ASIF)/Arbeitsgemeinschaft für Osteosynthesefragen (AO) and the North American Orthopedic Trauma Association (OTA)[2]. This classification system distinguishes between three degrees and types of instability. The Young–Burgess classification[3] utilizes a four-category system to classify pelvic ring fractures related to the direction of the force. These categories are further subdivided into three types based on the degree of severity. These classification systems aid surgeons in evaluating fracture patterns, determining treatment strategies, and predicting patient outcomes[4,5]. For informed surgical decision-making and preoperative planning, a comprehensive understanding of fracture morphology and location is essential when treating pelvic ring injuries.

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The sacroiliac joint (SIJ), covered anteriorly and posteriorly by strong ligaments, is the synovial joint between the ilium and sacrum. Morphologically, the SIJ is a diarthrodial joint[6]. The prevalence of spontaneous SIJ ankylosis ranges from 10% to 30% in the general population. SIJ ankylosis is the result of various factors, such as aging and genetic spondyloarthropathy[7-9]. By transmitting and dispersing truncal loads to the lower limbs, the function and biomechanics of the SIJ contribute to pelvic stability. After sacroiliac (SI) fixation, stress distribution changes in ankylosed SIJs and the biomechanics of the posterior pelvic ring are altered[10-12]. Therefore, the transformation of the SIJ due to ankylosis may alter force transmission and distribution as well as potentially impact the adjacent posterior ilium. However, this issue has not been investigated. The purpose of this study was to evaluate the relationship between SIJ ankylosis and posterior ilium fractures (PL) in pelvic ring injuries.

MATERIALS AND METHODS

1. Patient Study Design

This study was approved by the Institutional Review Board (IRB) of Inje University Busan Paik Hospital (IRB No. 2023-10-018-006), and the written informed consent was waived due to the study's retrospective design. From January 2004 to October 2023, the data was collected and retrospectively reviewed from 302 patients diagnosed with pelvic ring injury using pelvic radiographs and computed tomography (CT) scans. Pelvic ring injuries were identified according to the following Korean Classification of Diseases-8 (KCD-8) codes, which are adapted from the International Classification of Disease-10 (ICD-10): S32.1-S32.8 (excluding S32.4, fracture of acetabulum), S32.82, S32.83, S32.88, S32.89, S33.2, S33.3, S33.4, S33.6, and S33.7. The administrative discharge and emergency department logs from the institutional orthopedic department records were used to verify and reconcile discrepancies.

Exclusion criteria for the study were as follows: (1) pediatric pelvic ring injury, (2) combined pelvic and acetabular fractures, and (3) lack of CT imaging. A total of 272 patients meeting the inclusion criteria were enrolled in this study. Patients were divided into two cohorts based on the presence of SIJ ankylosis. Thus, 185 patients were included in the non-ankylosed group and 87 patients were included in the ankylosed group. Medical records were used to obtain patient data, including age, sex, body mass index (BMI), smoking status, medication use, comorbidities determined using the Charlson comorbidity index (CCI)[13], American Society of Anesthesiologists (ASA) physical status classification, preinjury walking ability, and injury mechanisms. Injury mechanisms were categorized into the following six groups: E, low-energy injury difficult to classify; L, ground-level fall; H, fall from height; P, pedestrian versus auto; M, motorized vehicle; and C, crush injury. The groups were further subdivided into high and low-energy injuries; E and L were classified as low energy, and H, P, M, and C were classified as high energy[14]. Fig. 1 shows the patient flow chart for both groups.

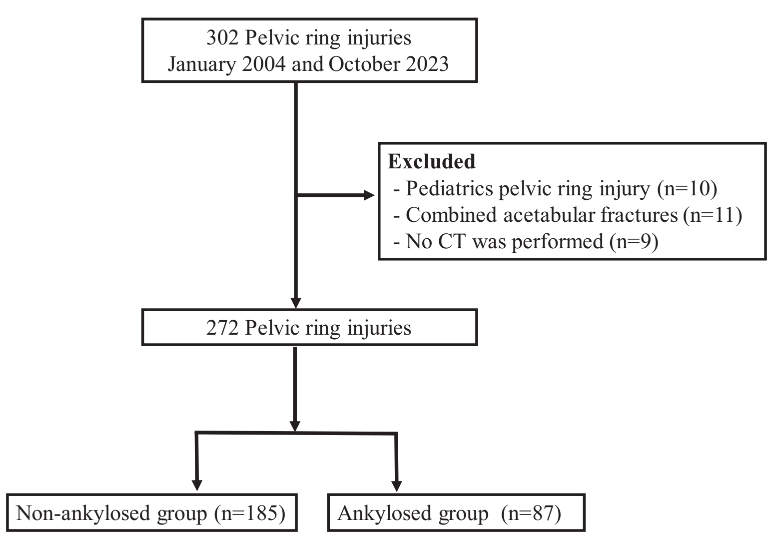

Fig. 1. Patient flow chart. CT: computed tomography.

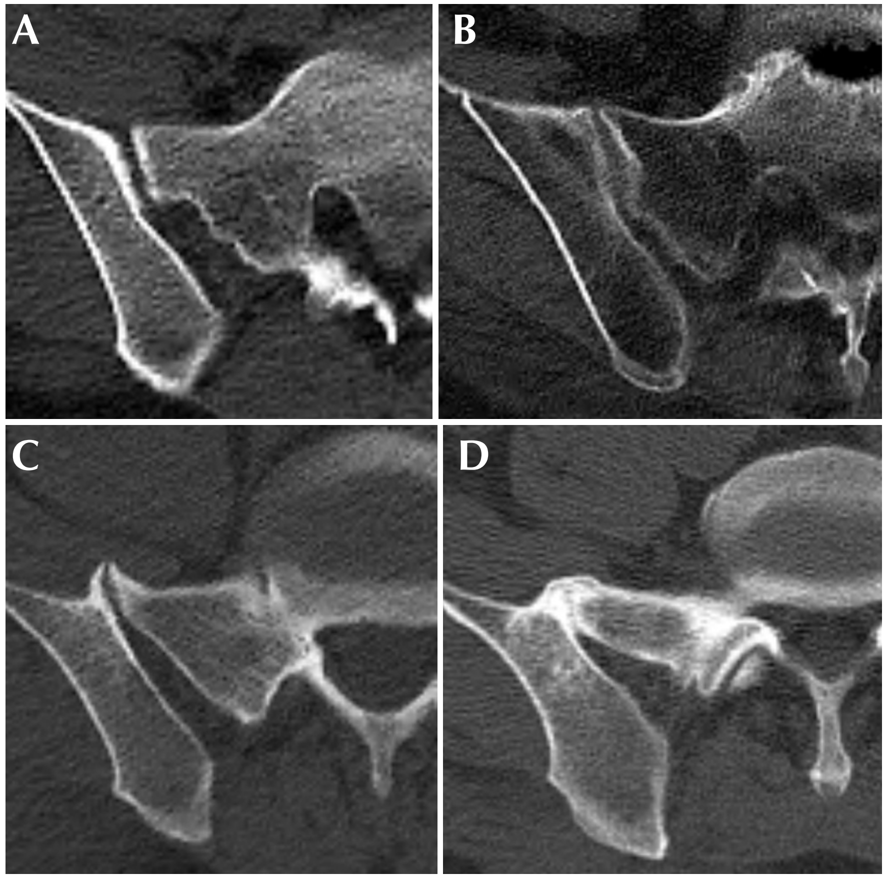

Fig. 2. Degeneration grading for the sacroiliac joint (SIJ) on axial computed tomography images. (A) Type 0, no abnormality. (B) Type 1, slight degenerative changes, characterized by mild subchondral sclerosis, osteophyte formation, or minimal joint-space narrowing. (C) Type 2, substantial degenerative changes. (D) Type 3, full SIJ ankylosis.

2. Evaluation

All CT scans were reviewed by a fellowship-trained orthopedic surgeon specializing in pelvic surgery. The scans were evaluated for SIJ ankylosis, PL, and fracture classification. SIJ ankylosis refers to degenerative fusion of the SIJ and is distinct from ankylosing spondylitis, a systemic inflammatory condition. The degree of degenerative changes in the SIJ was evaluated based on the CT scans. Patients were then classified into four categories: (0) normal images, revealing no abnormality; (1) slight degenerative changes, characterized by mild subchondral sclerosis, osteophyte formation, or minimal joint-space narrowing (JSN); (2) substantial degenerative changes, featuring large osteophytes, significant subchondral sclerosis, or definite JSN and new bridging osteophyte formation within the joint; and (3) full SIJ ankylosis. In this study, as shown in Fig. 2, SIJ ankylosis was defined as meeting the criteria of type (2) or (3)[9]. The entire patient cohort was evaluated for the prevalence of SIJ ankylosis and then stratified by age groups.

Any type of posterior ring injury characterized by fracture lines extending to the region posterior to the iliac pillar, with or without SIJ subluxation or dislocation, was defined as PL. Fracture lines were characterized as either complete or incomplete and displaced or nondisplaced. The iliac pillar is the bony thickening located above the acetabulum on the lateral surface of the ilium. It extends to the iliac tubercle, which is the thickening on the superior margin of the ilium. Excluding the anterior column, the PL area corresponds to the posterior region of the ilium (Fig. 3)[15].

In both the non-ankylosed and ankylosed cohorts, fracture patterns were compared between the pelvic fractures with and without PL. According to the ASIF/OTA classification of pelvic fractures[2], all fractures were classified into nine categories within the three main pelvic fracture types, ranging from A1 to C3 with increasing severity and instability. Type A includes stable pelvic ring injuries, with A1 indicating innominate

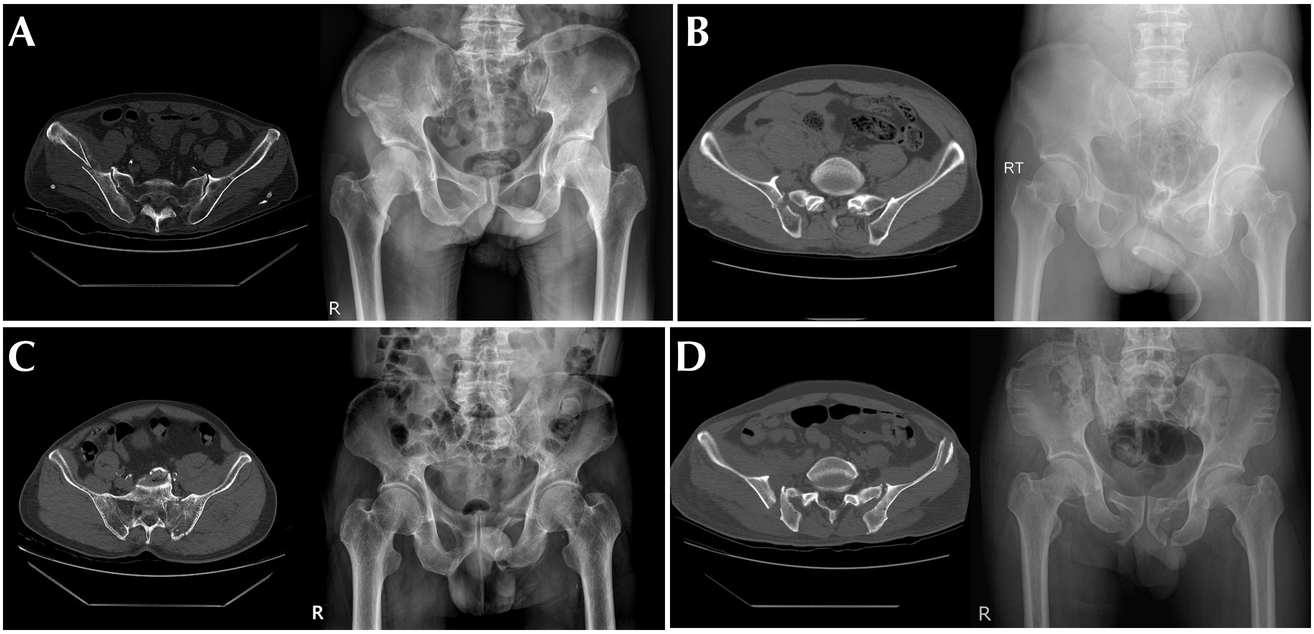

Fig. 3. Axial computed tomography and radiographic images of pelvic ring injuries with posterior ilium fractures in sacroiliac joint ankylosed patients. (A) Stable ring, type A2: Fracture of the innominate bone, direct blow, with bilateral type 2 sacroiliac joint (SIJ) degeneration. (B) Partially stable ring, type B1: Unilateral, partial disruption of the posterior arch, external rotation (open book) injury, with bilateral type 2 SIJ degeneration. (C) Partially stable ring, type B2: Unilateral, partial disruption of the posterior arch, internal rotation (lateral compression) injury, with bilateral type 3 SIJ degeneration. (D) Complete unstable ring, type C2: Bilateral, ipsilateral complete, contralateral incomplete disruption of the posterior arch, with bilateral type 3 SIJ degeneration.

bone avulsions, A2 indicating a direct blow to the innominate bone, and A3 representing caudal transverse lesions of the sacrum. Type B lesions are rotationally unstable. B1 includes open book injuries characterized by external rotation of one innominate bone, B2 includes lateral compression injuries with internal rotation of one innominate bone, and B3 includes bilateral rotational instability with one innominate bone rotated internally and the other rotated externally. Type C lesions include both rotational and vertical instability, with C1 indicating unilateral injuries, C2 indicating bilateral injuries with one rotationally unstable innominate bone and the other innominate bone rotationally and vertically unstable, and C3 representing bilateral injuries with both rotational and vertical instability. Laterality of SIJ ankylosis was also examined. Two patients with unilateral ankylosis contralateral to the fracture were included in the non-ankylosed group for the comparison of ASIF/OTA fracture patterns and logistic regression analysis. These two patients were among the 46 patients in the ankylosed group without PL.

Between the two groups, morphologic appearance of PLs was compared using CT scans to identify common fracture patterns. PL patterns were categorized into five groups based on the anatomic location and presence of sacral fracture as follows: IWE, iliac wing fracture extending to the posterior ilium; II, isolated ilium fracture; CS1, posterior iliac crescent fracture-dislocation (Day type I); CS2, Day type II; CS3, Day type III; +S, combined sacral fracture (Fig. 4). The crescent fractures were further subdivided based on the extent of SIJ involvement according to the Day classification as follows: type I, anterior third of the SIJ; type II, middle third of the SIJ; type III, posterior third of the SIJ. Injuries not fitting the Day classification scheme were categorized based on the ligamentous attachments to the posterior iliac fragment rather than the SIJ involvement[16,17]. This study analyzed 100 PLs in 99 patients, as one patient presented with bilateral PLs.

3. Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics (ver. 25.0; IBM Corp.). Statistical significance was set at $P<0.05$. Independent t-tests or Mann–Whitney's tests were used to compare continuous variables. Chi-square tests or Fisher's exact tests were

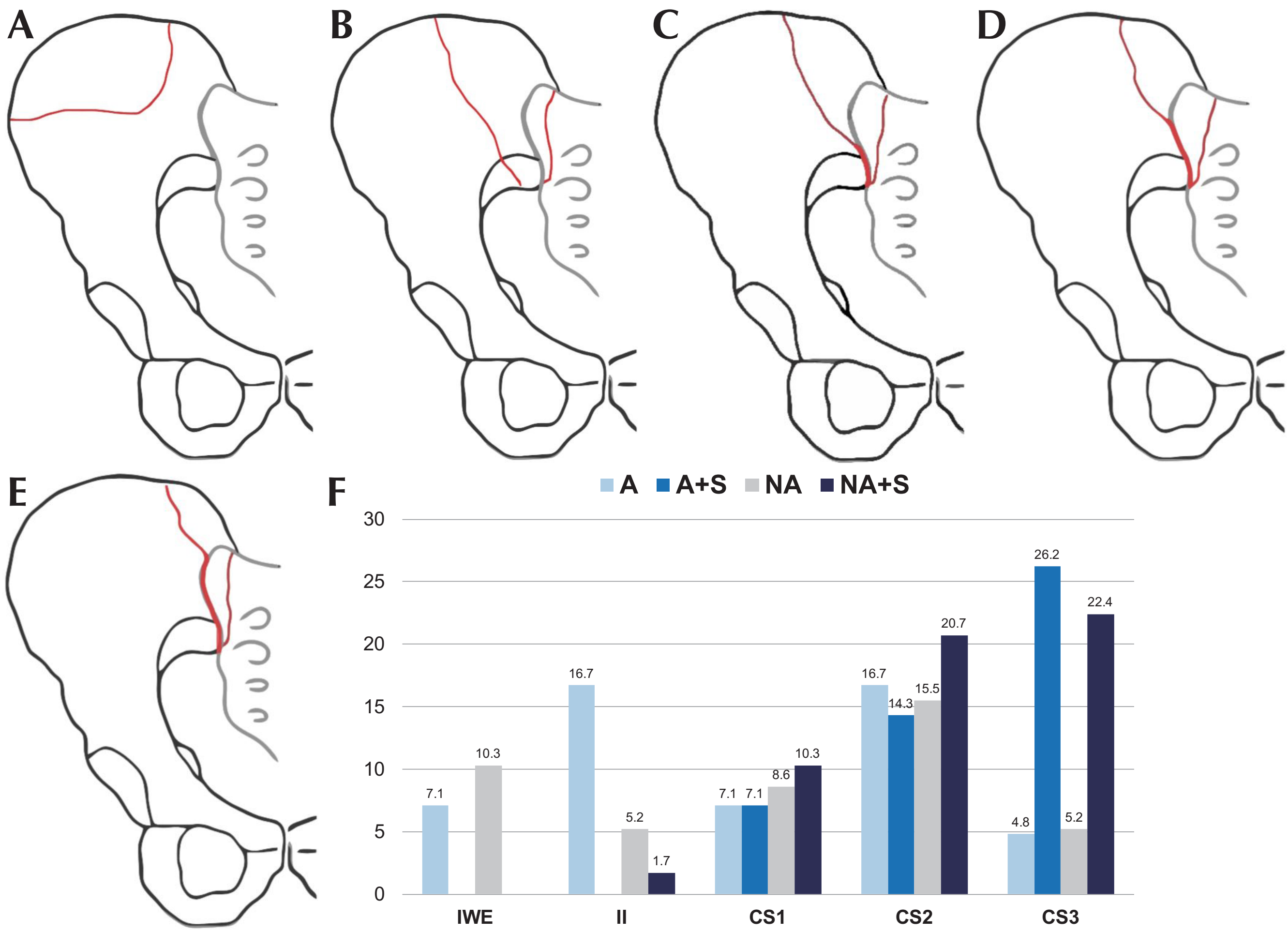

Fig. 4. Diagrammatic illustration of the five posterior ilium fracture (PL) types. (A) IWE: iliac wing fracture extending to the posterior ilium. (B) II: isolated ilium fracture. (C) CS1: crescent fracture, Day type I. (D) CS2: crescent fracture, Day type II. (E) CS3: crescent fracture, Day type III. (F) Graph showing the distribution of PL types according to the ankylosis status. X-axis depicts the PL types, and Y-axis reflects the percentage of patients with the specific PL type in the non-ankylosed and ankylosed groups. A: ankylosed group, +S: combined sacral fractures, NA: non-ankylosed group.

used to compare categorical variables. Binary logistic regression analyses were performed to determine the association between PL and SIJ ankylosis, with PL as the dependent variable and SIJ ankylosis, age, BMI, sex, and energy of injury mechanism as independent variables. Subgroup analysis, including bone mineral density (BMD), was conducted to evaluate the association between PL and SIJ ankylosis in low-energy pelvic fractures in patients ≥65 years of age.

RESULTS

Table 1 shows the demographic data for the non-ankylosed and ankylosed groups. SIJ ankylosis was observed in 87 (32.0%) of the 272 patients included in this study; 43% of patients ≥50 years old had ankylosis (Fig. 5). SIJ ankylosis was bilateral in 73 (83.9%) of the 87 patients. PL was significantly more common in the ankylosed group than in the non-ankylosed group (47.1% vs. 31.4%, P=0.012). Patients in the ankylosed group were significantly older (64.9 years vs. 53.5 years, P<0.001), predominantly male (58.6% vs. 37.8%, P=0.001), and had higher rates of medication use (55.2% vs. 40.0%, P=0.019). The CCI and ASA physical status scores were higher in the ankylosed group than in the non-ankylosed group (2.9 vs. 2.0 and 2.1 vs. 1.9, respectively). No significant differences in BMI, smoking status, walking ability, or mechanisms of injury were detected between the two groups.

The association between PL and SIJ ankylosis is summarized in Table 2. After adjusting for age, BMI, sex, and energy of injury mechanism, PL development

Table 1. Overall Demographic Data (n=272)

Characteristic	Non-ankylosed group (n=185)	Ankylosed group (n=87)	*P*-value
Posterior ilium fracture	58 (31.4)	41 (47.1)	0.012*
Age (yr)	53.5 (21-95)	64.9 (33-94)	<0.001*
Sex, male:female	70:115 (37.8:62.2)	51:36 (58.6:41.4)	0.001*
Body mass index (kg/m^2)	22.4±3.7	22.6±2.9	0.536
Smoking	23 (12.4)	13 (14.9)	0.614
Other medication	74 (40.0)	48 (55.2)	0.019*
Charlson comorbidity index	2.0±2.1	2.9±2.0	0.002*
ASA physical status score	1.9±0.9	2.1±0.8	0.021*
Preinjury walking ability			0.341
Independent walking	170 (91.9)	77 (88.5)	
Walking with aids	14 (7.6)	8 (9.2)	
Wheelchair	1 (0.5)	2 (2.3)	
Bed-ridden	0 (0)	0 (0)	
Mechanisms of injury[†]			0.954
E	5 (2.7)	2 (2.3)	
L	57 (30.8)	31 (35.6)	
H	31 (16.8)	14 (16.1)	
P	54 (29.2)	26 (29.9)	
M	24 (13.0)	9 (10.3)	
C	14 (7.6)	5 (5.7)	

Values are presented as number (%), mean (range), or mean±standard deviation.
ASA: American Society of Anesthesiologists physical status.
*P<0.05.
[†]The mechanism of injury was defined as 6 categories. E: low-energy injury difficult to classify, L: ground-level fall, H: fall from height, P: pedestrian versus auto, M: motorized vehicle, C: crush injury.

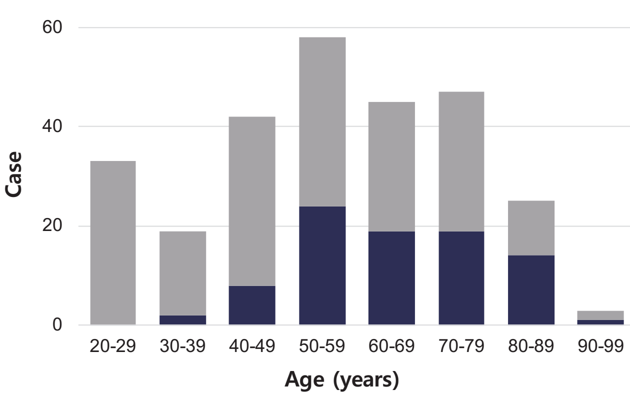

Fig. 5. Age and ankylosis sacroiliac joint (SIJ) distribution of study subjects (n=272). Navy bars, ankylosed SIJ; gray bars, non-ankylosed SIJ.

Table 2. Multivariate Logistic Regression Analysis of the Association between PL and SIJ Ankylosis

PL	OR (95% CI)	*P*-value
Ankylosis	2.15 (1.12-4.13)	0.022*
Energy of injury mechanism (high or low[†])	3.69 (1.74-7.80)	<0.001*
Age	1.01 (0.99-1.03)	0.178
BMI	0.94 (0.86-1.02)	0.141
Sex[†]	0.93 (0.49-1.77)	0.834

PL: posterior ilium fracture, SIJ: sacroiliac joint, OR: odds ratio, CI: confidence interval, BMI: body mass index.
*P<0.05.
[†]Reference group is low-energy injury mechanism and female.

was significantly associated with SIJ ankylosis (odds ratio 2.15, 95% confidence interval 1.12-4.13, P=0.022) and high-energy injury (odds ratio 3.69, 95% confidence interval 1.74-7.80, P<0.001). However, PL development was not associated with age, BMI, or sex (P=0.178, P=0.141, and P=0.834, respectively).

In patients aged ≥65 years, subgroup analysis, including BMD in low-energy pelvic fractures, revealed a statistically significant (P=0.044) 4.2-fold increase in the unadjusted odds of PL with SIJ ankylosis. However, this association did not remain significant after controlling for confounders (all P>0.05) (Table 3).

Table 4 presents the comparison of fracture types according to the ASIF/OTA classification between the non-ankylosed and ankylosed groups with and without

Table 3. Univariate and Multivariate Logistic Regression Analyses of the Association between PL and SIJ Ankylosis in Low-energy Pelvic Fractures in Patients Aged ≥65 Years

PL	Unadjusted		Adjusted	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Ankylosis	4.2 (1.04-17.02)	0.044*	3.14 (0.59-16.7)	0.179
Age			0.95 (0.84-1.07)	0.386
BMI			0.99 (0.76-1.29)	0.919
Sex†			4.17 (0.40-43.2)	0.232
BMD			1.24 (0.48-3.15)	0.655

PL: posterior ilium fracture, SIJ: sacroiliac joint, OR: odds ratio, CI: confidence interval, BMI: body mass index, BMD: bone mineral density.
*P<0.05.
†Reference group is female.

Table 4. Comparison of Fracture Types between Non-ankylosed and Ankylosed Groups with and without PL according to the ASIF/OTA Classification

	ASIF/OTA classification	Non-ankylosed group	Ankylosed group	*P*-value
With PL		(n=58)	(n=41)	0.704
	A1	0 (0)	0 (0)	
	A2	6 (10.3)	3 (7.3)	
	A3	0 (0)	0 (0)	
	B1	1 (1.7)	1 (2.4)	
	B2	39 (67.2)	25 (61.0)	
	B3	8 (13.8)	5 (12.2)	
	C1	3 (5.2)	6 (14.6)	
	C2	1 (1.7)	1 (2.4)	
	C3	0 (0)	0 (0)	
Without PL		(n=129)	(n=44)	0.100
	A1	1 (0.8)	3 (6.8)	
	A2	48 (37.2)	13 (29.5)	
	A3	3 (2.3)	1 (2.3)	
	B1	14 (10.9)	1 (2.3)	
	B2	55 (42.6)	22 (50.0)	
	B3	2 (1.6)	1 (2.3)	
	C1	5 (3.9)	2 (4.5)	
	C2	1 (0.8)	0 (0)	
	C3	0 (0)	1 (2.3)	

Values are presented as number (%).
PL: posterior ilium fracture, ASIF/OTA: Association for the Study of Internal Fixation/Orthopedic Trauma Association.

PL. Among the pelvic fractures with PL, the most common fracture patterns in the ankylosed group were types B2 (n=25, 61.0%), C1 (n=6, 14.6%), and B3 (n=5, 12.2%). The most common fracture patterns in the non-ankylosed groups were types B2 (n=39, 67.2%) and B3 (n=8, 13.8%). In 90% of patients in both groups, injuries were classified as type B or C, but no significant differences were detected (*P*=0.704). Among the pelvic fractures without PL, the most common fracture patterns in the ankylosed group were types B2 (n=22, 50.0%) and A2 (n=13, 29.5%). The most common fracture patterns in the non-ankylosed groups were types B2 (n=55, 42.6%), A2 (n=48, 37.2%), and B1 (n=14, 10.9%). Fracture patterns did not significantly differ between the ankylosed and non-ankylosed groups (*P*=0.100).

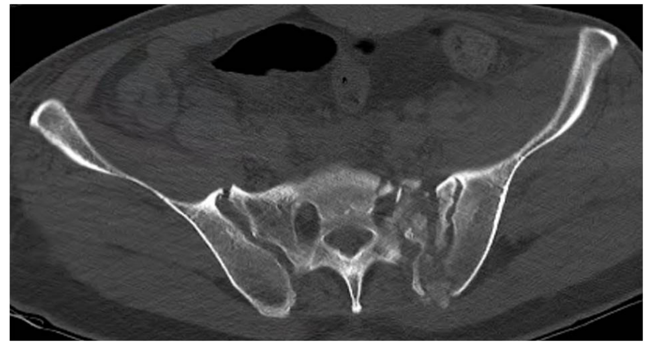

Fig. 6. Axial computed tomography image of a 54-year-old male with bilateral sacroiliac joint ankylosis. Young–Burgess lateral compression III injury with crushing mechanism. Left side shows Day type III crescent fracture with ipsilateral sacral fractures.

Fig. 4 shows the comparison of PL types between the ankylosed (n=42) and non-ankylosed (n=58) groups. Combined sacral fractures were less frequent in the ankylosed group than in the non-ankylosed group (47.6% vs. 55.2%), while isolated ilium fractures were more common (16.7% vs. 5.2%). Crescent fractures were more common in the non-ankylosed group than in the ankylosed group (76.2% vs. 82.7%). Between the two cohorts (62.5% vs. 64.6%), the combined sacral fracture ratio among the patients with crescent fractures was similar. Combined sacral fractures were less common among the patients with CS1 and CS2 fractures in the ankylosed group than those in the non-ankylosed group (47.4% vs. 56.3%). However, combined sacral fractures were more commonly found among the patients with CS3 fractures in the ankylosed group than those in the non-ankylosed group (84.6% vs. 81.3%) (Fig. 6).

DISCUSSION

The findings of this study revealed a significant association between SIJ ankylosis and PL in pelvic ring injury. The ankylosed group exhibited a significant

2.15-fold higher odds ratio for developing PL as compared to the non-ankylosed group. A theoretical background regarding force transmission was explored to support these findings. It is hypothesized that changes in energy propagation, combined with the distinct anatomical features of the posterior ilium, contribute to the observed association between PL and ankylosis. In pelvic ring injuries, external forces transmitted through the innominate bone interact with the boundary at the SIJ, potentially resulting in altered energy transmission and reflection. When a mechanical wave encounters this boundary, part of it is reflected back into the original medium. Characteristics of this reflected wave are influenced by the properties of the medium and the angle of incidence, with variations in density and elasticity at the boundary affecting the reflection[18]. The posterior ilium may be particularly susceptible to these changes as it encompasses the thinnest and lowest bone mass area of the ilium and is located adjacent to the SIJ[19]. Therefore, the injury patterns observed in the posterior ilium are potentially influenced by the altered mechanics of energy transmission and reflection caused by the transformation of the SIJ due to ankylosis.

Investigations into the biomechanical properties of SIJ ankylosis are limited. In a finite element analysis (FEA) of a SIJ fusion model, Shi et al.[10] detected smaller movements and changes in stress distribution when compared with the SIJ contacting model. In another FEA of a SIJ fixation model, Bruna-Rosso et al.[11] detected a reduction in SIJ motion. Specifically, the rotational motion between the sacrum and ilium was reduced. In a biomechanical study using cadavers for SI screw fixation, Cross et al.[12] reported a decrease in the mean range of motion and lateral bending motion of the SIJ. Further biomechanical studies focusing on SIJ joint stiffness, load distribution, and the effects of ankylosis on adjacent structures are needed.

Several studies have reported on the prevalence and risk factors for ankylosed SIJ. Using CT scans, Eno et al.[9] assessed SIJ sclerosis, osteophyte formation, and JSN in 373 asymptomatic patients. After classifying the degree of SIJ degeneration from type 0 (no degeneration) to type 3 (full SIJ ankylosis), the overall prevalence of substantial SIJ degeneration corresponding to types 2 and 3 was 30.5%. Furthermore, ankylosis prevalence, starting from the age of 30, increased with age, and 45% of the patients aged 60 years and older had a substantial degenerative change in the SIJ. In a study of 204 patients using CT, Gahleitner et al.[20] detected a 24% prevalence of SIJ ankylosis in patients with and without spinal pathologies. They also found that older age and being male were risk factors for SIJ ankylosis. In this study, the prevalence of SIJ ankylosis was 32.0%, with a higher ratio of males. Also, 43% of patients ≥50 years exhibited ankylosis. These results are consistent with previous studies[7-9,20]. Furthermore, based on the only two studies conducted to date, the bilaterality rate of SIJ ankylosis was ≤82.6%, which remains contentious depending on the criteria used for grading and differentiation of ankylosis[20,21]. Consistent with previous studies, our study found SIJ ankylosis bilaterality in 83.9% of the patients.

The ankylosed SIJ group in this study was, on average, older than the non-ankylosed SIJ group. Several studies on geriatric pelvic fractures noted that types B and C are more common fracture patterns in older individuals[22,23]. As PL is one of the fracture morphologies constituting the posterior ring fracture in types B and C, it raises the question of whether the findings of this study simply reflect a phenomenon commonly observed in geriatric pelvic ring injuries. Nevertheless, using multivariate regression analysis, a significant association between PL and SIJ ankylosis was detected after controlling for explanatory variables including age. Our study revealed a significant association between PL and SIJ ankylosis in low-energy pelvic fractures in patients aged ≥65 years through univariate regression analysis. However, after adjusting for explanatory variables, including BMD, this association did not persist in multivariate regression analysis. Possible contributors to the lack of statistically significant results across all multivariate parameters include the limited sample size of 44 recorded BMD evaluations and the absence of matched subgroup cohorts. In the future, larger cohort studies are warranted to validate these findings.

Differences in fracture types with and without PL were determined between the ankylosed and non-ankylosed groups. No significant differences in fracture types were detected between the two groups.

Lateral compression (type B2) fractures predominated among the patients with PL in both groups. This predominance of type B2 fractures may have occurred because most PLs in this study were crescent fractures. Furthermore, 90% of fractures in both groups were partially or completely unstable (types B or C). This finding may be the reason that high-energy injuries exhibited a 3.69 times stronger association with PL. As highlighted in Table 2, energy level is crucial in determining the development of PL as it significantly influences the posterior pelvic fracture patterns. However, this study also underscores the significant impact of ankylosis on PL. Although both factors are important, our findings emphasize that ankylosis plays a critical role and should be carefully considered in understanding posterior pelvic fracture patterns.

Eighty percent of the fractures in both groups were either type B2 or A2 among the patients without PL. Our results align with previous studies indicating that Young–Burgess lateral compression type I injury predominates in pelvic ring injuries as 85% of the A2 fractures in the present study cohort were only anterior-ring fractures[24,25]. Furthermore, the ratio of open book (type B1) fractures was higher in the younger non-ankylosed group than in the ankylosed group (10.9% vs. 2.3%). This result is likely due to the fact that all type B1 fractures without PL were observed in young adults with high-energy trauma.

The results of this study revealed that, while isolated ilium fractures were more common, combined sacral fractures and crescent fractures were less common in the ankylosed group. This distinction might be due to the transformed SIJ acting as a mechanical barrier to energy transmission, leading to isolated ilium fractures instead of crescent or combined sacral fractures. Thus, combined sacral fractures were less frequent in patients with CS1 and CS2 fractures in the ankylosed group compared to those in the non-ankylosed group. However, combined sacral fractures were more commonly seen in patients with CS3 fractures in the ankylosed group than in those in the non-ankylosed group. This result is likely due to the strong and stable iliolumbar and posterior SI ligaments near the posterior third of the SIJ, which have a complex effect on force transmission.

This study has several limitations. First, selection bias and errors in assessing injury mechanisms may have been introduced by the retrospective study design, potentially affecting the findings. Furthermore, clinical follow-up data were not included in the study analyses. Second, BMD and quality, which could have affected the association with PL, were not evaluated. BMD was examined in only a few cases included in this study. Thus, a thorough BMD analysis could not be conducted. Although univariate analysis provided significant results among the patients aged ≥65 years with low-energy injury, these findings did not persist in multivariate analysis. Future large-scale studies with comprehensive BMD assessments are warranted. Third, the groups were not age-, sex- or BMI-matched. Thus, the significance of our results may have been underpowered. However, these confounders were accounted for in a separate regression analysis, which strengthened the validity of our findings. Fourth, the study did not directly investigate biomechanical force transmission. Further research is needed to refine and support the theoretical framework of the findings, particularly in the context of SIJ ankylosis. Lastly, the methods used to evaluate SIJ degenerative changes and define ankylosis may introduce bias. More precise classification criteria and methods are required to reduce potential biases and improve reliability.

The analysis of pelvic ring injury patterns among patients with ankylosed SIJ was unique despite these limitations. The results provide valuable insights into the unique fracture morphology in pelvic injuries in ankylosed SIJ patients, particularly PL involvement combined with or without any types of posterior ring injury. Posterior iliac fractures and fracture-dislocation SIJs involving the ilium typically disrupt the continuity of the posterior pelvic ring, resulting in an unstable hemipelvis. Understanding fracture characteristics in posterior pelvic ring injuries with ankylosed SIJ may assist surgeons in classifying fractures and during preoperative planning.

CONCLUSION

SIJ ankylosis is closely associated with PL in pelvic ring injuries. Changes in the stiffness and elasticity of the SIJ due to ankylosis may potentially impact the pattern of posterior ring fractures.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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