Correlation between Acetabular Anteversion with a False-Profile View and Spinopelvic Parameters in Adult Spinal Deformity after Long-Segment Corrective Spinal Surgery

Ichiro Kawamura[1], Hiroyuki Tominaga[1], Hiroto Tokumoto[1], Masato Sanada[1], Takuma Ogura[1], Tomoki Kuroshima[1], Junichi Kamizono[2] and Noboru Taniguchi[1]

1) Department of Orthopaedic Surgery, Graduate School of Medicine and Dental Science, Kagoshima University, Kagoshima, Japan
2) Department of Orthopaedic Surgery, Sendai Medical Association Hospital, Kagoshima, Japan

Abstract:

Introduction: Studies describing the relationship between the hip and spine have reported that corrective spinal surgery for adult spinal deformity (ASD) affects the orientation of the acetabulum. However, the extent to which spinal correction in ASD affects acetabular anteversion in the standing position is unclear, especially after total hip arthroplasty, for which dislocation is a concern. The purpose of this study was to evaluate changes in anterior acetabular coverage in the upright position due to extensive correction surgery for ASD.

Methods: Thirty-six consecutive patients who had undergone spinal corrective surgery from the thoracolumbar region to the pelvis were enrolled and evaluated. The ventral-central-acetabular (VCA) angle and anterior acetabular head index (AAHI) were measured with a false-profile view to evaluate the relationship between acetabular anteversion in the standing position and spinopelvic parameters before and after surgery. The spinopelvic parameters measured included thoracic kyphosis, pelvic incidence, pelvic tilt (PT), sacral slope, lumbar lordosis (LL), sagittal vertical axis, and global tilt.

Results: The VCA angle and AAHI were significantly increased after spinal deformity correction ($p<0.001$). The changes in LL and PT were correlated with the VCA angle (LL: right, $\rho=0.56$; left, $\rho=0.55$, $p<0.001$; PT: right, $\rho=-0.59$; left, $\rho=-0.64$, $p<0.001$) and AAHI (LL: right, $\rho=0.51$; left, $\rho=0.58$, $p<0.01$; PT: right, $\rho=-0.52$; left, $\rho=-0.59$, $p<0.01$), respectively. Linear regression analysis revealed that a 10° increase in LL results in 1.4°-1.9° and 1.6%-2% increases in the VCA angle and AAHI, respectively.

Conclusions: Surgical correction for ASD significantly affects sagittal spinopelvic parameters, resulting in increased acetabular anteversion. The anterior coverage of the acetabulum in the postoperative standing position could be predicted with the intraoperatively measured LL, and evaluation using a false-profile was considered useful for treating ASD, particularly in patients after total hip arthroplasty.

Keywords:
adult spinal deformity, false-profile view, acetabular anteversion, lumbar lordosis, pelvic tilt

Spine Surg Relat Res 2024; 8(3): 330-337
dx.doi.org/10.22603/ssrr.2023-0273

Introduction

Adult spinal deformity (ASD) is often complicated by sagittal spinopelvic deformities such as loss of lumbar lordosis and pelvic retroversion[1], pelvic incidence (PI) and lumbar lordosis (LL) match, and that pelvic tilt (PT) improvement correlates with health-related quality of life metrics (HRQoLs)[2]. Therefore, the main goals of many surgeries for ASD that require extensive fixation include an improvement in sagittal balance by improving LL and PT.

In studies describing the relationship between the hip and the spine, corrective spinal surgery was found to affect acetabular orientation, including changes in anterior dislocation[3,4]. In addition, abnormal spine-pelvis-hip motion due to lumbosacral lesions is thought to impinge implants, leading to dislocation[5,6]. Hence, spinal deformity surgery after total

Corresponding author: Ichiro Kawamura, k-ichiro@m2.kufm.kagoshima-u.ac.jp
Received: November 11, 2023, Accepted: November 28, 2023, Advance Publication: February 14, 2024

hip arthroplasty (THA) can significantly contribute to the risk of instability and dislocation[7]. Some reports have described the extent to which extensive spinal fusion surgery extending to the pelvis alters acetabular coverage in the standing position[8], as evaluated from the coronal plane using the Lewinnek method[9]. However, no reports have directly assessed how corrective long spinal fusion with pelvic fusion for ASD alters acetabular anteversion in the standing position. In patients with hip dysplasia, the ventral-central-acetabular (VCA) angle and anterior acetabular head index (AAHI) on false-profile radiographs have been measured and reported for anterior acetabular coverage in the standing position[10]. Therefore, the purpose of this study was to evaluate and quantify the changes in acetabular anteversion parameters in a standing position with a false-profile view in patients with ASD along with spinal corrective long fusion with pelvic fixation and to analyze the relationship between the sagittal parameters of the spine and postoperative changes. A deeper understanding of the relationship between these radiographic metrics can improve surgical planning for patients with the hip and spine lesions.

Materials and Methods

Patients

This retrospective observational study protocol was approved by the institutional review board of the author's affiliated institution, and an opt-out policy was employed. A retrospective analysis of radiographic and clinical data was conducted in compliance with the ethical principles outlined in the 1964 Declaration of Helsinki. We reviewed 36 consecutive patients (right hip, 35; left hip, 35) who underwent spinal fusion surgery for adult spinal deformity (ASD) between October 2018 and March 2023 at our institutes. One right hip was excluded because of high dislocation due to acetabular dysplasia, and one left hip was excluded because of defects in the postoperative false-profile view. The subjects were patients with a diagnosis of degenerative thoracolumbar kyphosis or kyphoscoliosis who underwent long-segment spinal fusion from the lower thoracic vertebra (T9 or T10) to the pelvis, excluding patients who underwent domino extension. Patients met the inclusion criteria based on the following parameters: a sagittal vertical axis (SVA) exceeding 50 mm, PT greater than 25°, or thoracic kyphosis (TK) between the T5 and T12 vertebrae exceeding 60°. The exclusion criteria comprised cases with inadequate radiographic visibility for assessing spinal parameters on full-spine standing anteroposterior and lateral radiographs obtained during routine pre- and postoperative examinations.

Surgical procedure

All surgeries were performed in a two-stage procedure: posterior dissection using posterior column osteotomy grade 1 or 2[11] and anterior surgery with lateral lumbar interbody fusion in the first stage of surgery and posterior corrective fusion from the lower thoracic region (T9 or 10) to the pelvis in the second stage. Seven patients underwent additional grade 3 or 4 posterior column osteotomy[11] during the two-stage surgery. All operations were performed with all-pedicle screw constructions, and spinopelvic fixation was performed using iliac screws or S2 alar-iliac screws.

Radiographic assessment

All patients underwent full-length standing lateral spine radiography in a hands-on clavicle position and false-profile radiography preoperatively and at first standing after the operation.

Spinopelvic parameters, including TK, LL, lower-lumbar lordosis (lower LL), PI minus LL (PI-LL), PI, PT, sacral slope (SS), SVA, and global tilt (GT), were measured. TK was defined as the angle connecting the T5 superior endplate and the T12 inferior endplate. LL was defined as the angle between the superior L1 and the S1 endplate. Lower LL was defined as the angle between the superior L4 and S1 endplate (Fig. 1a). PI was defined as the angle between the perpendicular line of the sacral plate and the line connecting the center of the sacral plate and the hip axis. PT was defined as the angle formed by a line connecting the center of the sacral endplate and the center of the femoral heads in relation to a vertical line. SS was defined as the angle between a horizontal reference line and the inclination of the sacral endplate (Fig. 1b). SVA was calculated as the separation between the C7 plumb line and the posterior-superior aspect of S1. GT was defined as the angle between the line connecting the center of the C7 vertebra to the center of the sacral plate and the line connecting the center of the sacral plate to the hip axis (Fig. 1c). TK was considered positive if the curve was kyphotic, and LL and lower LL were considered positive in the presence of lordotic curvature.

False-profile radiographs (Fig. 2) were taken in the standing position at an angle of 65° between the pelvis and the film, as previously described[10]. The VCA angle and AAHI were measured on this false-profile view. The VCA angle was defined as the angle between a line between the anterior edge of the dense shadow of the subchondral bone slightly posterior to the anterior edge of the acetabulum and the center of the femoral heads and a vertical line (Fig. 3). The AAHI was defined as the distance between the line of the most posterior aspect of the femoral head and the anterior aspect of the acetabulum (A) divided by the distance between the most posterior aspect and the most anterior aspect of the femoral head (B), which was then converted to a percentage ((A/B)×100) (Fig. 4). The pre- and postoperative changes in each parameter were described using delta (Δ) in front of the name of the parameter (e.g., ΔLL).

Interobserver and intraobserver reliability

The intraclass correlation coefficients (ICC) for the acetabular anterior coverage parameters, namely, VCA angle and AAHI, were calculated within and between the observ-

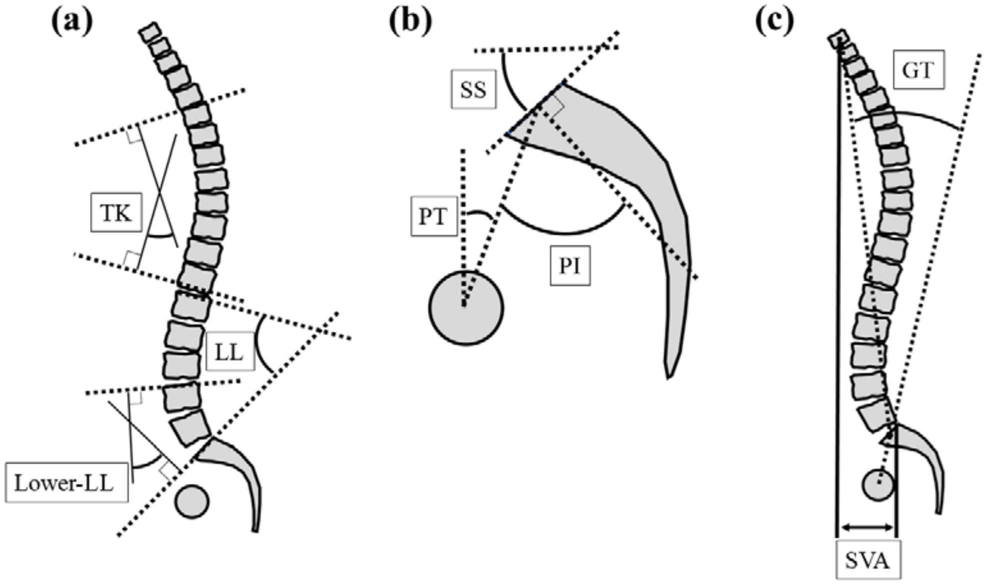

Figure 1. Spinopelvic parameters are measured in the upright position on lateral radiographs of the spine: (a) thoracic kyphosis (TK), lumbar kyphosis (LL), and lower LL; (b) pelvic incidence (PI), pelvic tilt (PT), and sacral tilt (SS); (c) sagittal plane vertical axis (SVA) and global tilt (GT).

Figure 2. Figure showing a false-profile view of the left hip.

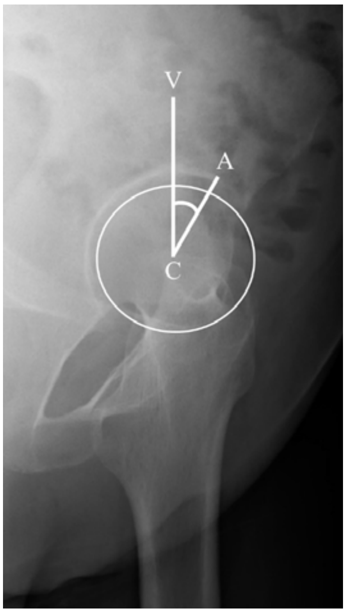

Figure 3. Figure showing the ventral–central–acetabular angle (V, vertical line from the femoral head center; C, femoral head center; A, anterior margin of dense subchondral bone shadow slightly posterior to the anterior margin of the acetabulum).

ers. Two independent observers (IK and MS) conducted all measurements and recorded the data. Measurements were collected at two distinct time points, with a minimum interval of 2 weeks. The ICC was calculated using two-way analysis of variance.

Statistical analysis

All statistical analyses, except for those of inter- and intraobserver reliability, were performed using JMP Pro statistical software (version 16.0, SAS Institute, NC, USA). Intra- and interobserver reliability were assessed using BellCurve for Excel (version 4.04, Social Survey Research Information Co., Ltd., Tokyo, Japan), which is an add-in for Excel software for statistical evaluation. Case analysis was used, and data were summarized by the mean±standard deviation or range for numeric variables. We applied a paired t-test to analyze the measured values of the spinopelvic and acetabular coverage parameters and compared the pre- and postop-

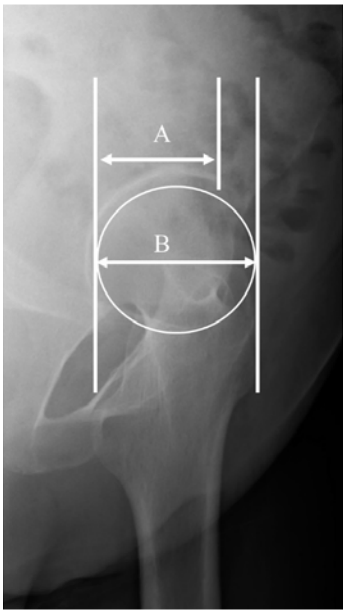

Figure 4. Figure showing the anterior acetabular head index ((A/B)×100).

Table 1. Demographic Characteristics of the Patients.

Parameter	Value
Number of patients	36
Number of hips	
Right/Left (n)	35/35
Sex	
Male/Female (n)	8/28
Age (years)	68.1±7.8
Body mass index (kg/m^2)	22.6±3.5
Diagnosis	
History of total hip arthroplasty (n)	2
Degenerative kyphosis (n)	14
Degenerative kyphoscoliosis (n)	22
Number of fusion levels	8.0±0.1
T9 to pelvis (n)	1
T10 to pelvis (n)	35
Posterior column osteotomy	
≤grade 2 (n)	29
≥grade 3 (n)	7

Notes:
Mean±standard deviation and (minimum-maximum range) are shown for age, body mass index, and number of fusion levels.

erative conditions. The impact of alterations in spinopelvic parameters on changes in acetabular anterior coverage parameters was explored using bivariate correlation analysis and linear regression analysis. Statistical significance was indicated for p<0.05.

Table 2. Changes in Spinopelvic and Acetabular Parameters before and after Surgery.

Parameter	Value (mean±SD)		p
Spinopelvic parameters	Preoperation	Postoperation	
TK (°)	10.9±15.4	27.6±10.4	<0.001
LL (°)	8.3±17.4	45.5±9.7	<0.001
Lower-LL (°)	18.4±14.4	30.8±7.7	<0.001
PI-LL (°)	39.7±17.0	2.5±9.3	<0.001
PT (°)	31.8±10.5	17.7±7.7	<0.001
SS (°)	15.8±9.4	29.5±7.3	<0.001
SVA (mm)	112.1±62.5	30.9±35.4	<0.001
GT (°)	41.6±16.3	17.6±10.2	<0.001
Acetabular parameters			
VCA angle			
Right hip (°)	25.3±5.7	32.3±4.8	<0.001
Left hip (°)	25.8±5.8	32.7±4.3	<0.001
AAHI			
Right hip (%)	74.8±7.0	81.9±5.0	<0.001
Left hip (%)	75.8±6.8	82.3±4.2	<0.001

Abbreviations: AAHI, anterior acetabular head index; GT, global tilt; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SD, standard deviation; SS, sacral slope; SVA, sagittal vertebral axis; TK, thoracic kyphosis; VCA angle, ventral-central-acetabular angle.
Notes:
The data in the table are presented as the mean±SD.
Pre- and postoperative values were compared using the paired t test.
Statistical significance was set at p<0.05.

Results

Demographic data

The demographic data of the patients are shown in Table 1. A total of 36 consecutive patients (right, 35 hips; left, 35 hips) met the study inclusion criteria. There were 28 women and 8 men. The age of the patients was 68.1±7.8 (range, 49-80) years, and the body mass index was 22.6±3.5 (range, 15.8-30.8) kg/m^2. The number of fusion levels was 8.0±0.1 (range, 8-9), and 7 patients underwent grade 3 or higher posterior column osteotomy.

Intra- and interobserver reliability

The intra- and interobserver reliability for acetabular dislocation were assessed using the ICCs for the VCA angle and AAHI: 0.95 (95% CI: 0.89-0.98) and 0.96 (95% CI: 0.91-0.98), and 0.97 (95% CI: 0.93-0.98) and 0.94 (95% CI: 0.85-0.97), respectively.

Changes in spinopelvic parameters and acetabular anteversion after surgery

The sagittal parameters, including TK, LL, Lower LL, PI-LL, PT, SS, SVA, and GT, measured on X-ray showed significant improvements postoperatively (p<0.01). The acetabular parameters (VCA angle and AAHI) were also increased after surgery, indicating increased acetabular anteversion (p<0.01) (Table 2).

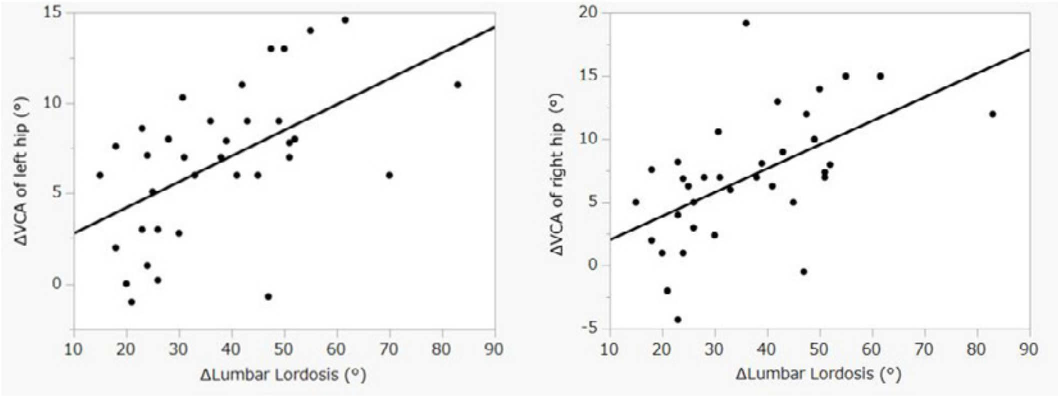

Figure 5. Scatterplots illustrating the linear regression of the change in ventral–central–acetabular (ΔVCA) angle and change in lumbar lordosis after surgery (left figure, left hip; right figure, right hip).
The pre- to postoperative changes in each parameter are indicated using delta in front of the name of the parameter (e.g., ΔVCA).

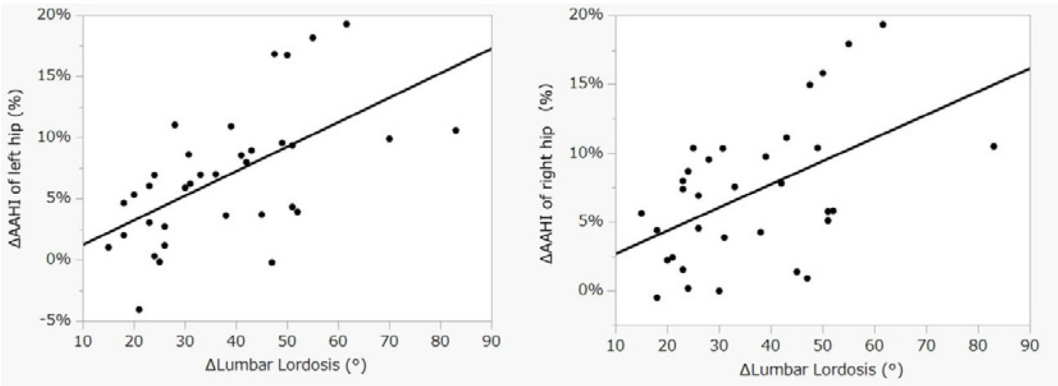

Figure 6. Scatterplots illustrating the linear regression of the change in the anterior acetabular head index (ΔAAHI) and change in lumbar lordosis after surgery (left figure, left hip; right figure, right hip).
The pre- to postoperative changes in each parameter are indicated using delta in front of the name of the parameter (e.g., ΔAAHI).

Correlations between spinopelvic parameters and acetabular parameters

The spinal parameters that were correlated with ΔVCA and ΔAAHI indicated changes in acetabular coverage. Positive correlations were found for ΔLL (ΔVCA: right, r=0.56, p<0.001; left, r=0.55, p<0.001; ΔAAHI: right, r=0.51, p<0.01; left, r=0.58, p<0.01) (Fig. 5, 6) and ΔSS (ΔVCA: right, r=0.61, p<0.001; left, r=0.64, p<0.001; ΔAAHI: right, r=0.52, p<0.01; left, r=0.56, p<0.01). Negative correlations were observed for ΔPT (ΔVCA: right, r=−0.59, p<0.001; left, r=−0.64, p<0.001; ΔAAHI: right, r=−0.52, p<0.01; left, r=−0.59, p<0.01) and ΔGT (ΔVCA: right, r=−0.48, p<0.01; left, r=−0.50, p<0.01; ΔAAHI: right, r=−0.45, p<0.01; left, r=−0.46, p<0.01) (Table 3).

Linear regression analysis of ΔLL, ΔPT, and ΔSS with the acetabular parameters ΔVCA and ΔAAHI revealed that a 10° gain in ΔLL increased VCA by 1.4°-1.9° and AAHI by 1.6%-2.0%. It was also found that a decrease in ΔPT and an increase in ΔSS of approximately 10° each increased VCA and AAHI by approximately 3° and 3%, respectively (Table 4).

Discussion

This study is the first report to show that the amount of change in acetabular anteversion in standing on a false-profile view correlates with the amount of change in LL, which can be measured intraoperatively in patients with ASD. ASD is associated with worsened spinal sagittal alignment, particularly lumbar kyphosis, and increased pelvic retroversion for maintaining spinal-pelvic alignment[1,2]. Thus, in terms of the compensatory mechanisms of the human upright posture, improving spinal sagittal alignment improves compensation and increases acetabular coverage, along with pelvic anteversion[3,4,8]. These findings suggest that correcting ASDs with increased PT, especially when lumbar kyphosis is acquired, may decrease PT and may increase anterior and lateral acetabular coverage. Furthermore, because the values of LL in the intraoperative and postoperative standing posi-

Table 3. Correlations between the Pre- to Postoperative Changes in Spinopelvic and Acetabular Anteversion Parameters.

Parameter		ΔVCA angle		ΔAAHI	
		Right	Left	Right	Left
ΔTK	*r*	0.14	0.02	0.24	0.22
	p	0.39	0.9	0.18	0.20
ΔLL	*r*	**0.56*****	**0.55*****	**0.51****	**0.58****
	p	<0.001	<0.001	<0.01	<0.01
ΔLower-LL	*r*	0.17	0.26	0.25	0.26
	p	0.31	0.10	0.15	0.12
ΔPT	*r*	**−0.59*****	**−0.64*****	**−0.52****	**−0.59****
	p	<0.001	<0.001	<0.01	<0.01
ΔSS	*r*	**0.61*****	**0.64*****	**0.52****	**0.56****
	p	<0.001	<0.001	<0.01	<0.01
ΔSVA	*r*	−0.28	−0.28	−0.40*	−0.24
	p	0.098	0.11	0.022	0.15
ΔGT	*r*	**−0.48****	**−0.50****	**−0.45****	**−0.46****
	p	<0.01	<0.01	<0.01	<0.01

Abbreviations: AAHI, anterior acetabular head index; GT, global tilt; LL, lumbar lordosis; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertebral axis; TK, thoracic kyphosis; VCA angle, ventral-central-acetabular angle.
Notes:
* p<0.05.
** p<0.01.
*** p<0.001.
The parameters were evaluated through bivariate correlation analysis.
Statistical significance was set at p<0.05.
Statistically significant correlations are shown in bold.

Table 4. Linear Regression Analysis of Parameters Predicting Changes in VCA Angle and AAHI after the Operation.

Bivariate relationship	Formula	Coefficient of determination	p
ΔVCA and ΔLL			
Rt hip (°)	ΔVCA=0.14+0.19ΔLL	0.31	<0.001
Lt hip (°)	ΔVCA=1.36+0.14ΔLL	0.30	<0.001
ΔVCA and ΔPT			
Rt hip (°)	ΔVCA=2.7−0.31ΔPT	0.35	<0.001
Lt hip (°)	ΔVCA=2.6−0.28ΔPT	0.42	<0.001
ΔVCA and ΔSS			
Rt hip (°)	ΔVCA=2.7+0.31ΔSS	0.37	<0.001
Lt hip (°)	ΔVCA=2.9+0.27ΔSS	0.42	<0.001
ΔAAHI and ΔLL			
Rt hip (%)	ΔAAHI=0.99+0.16ΔLL	0.26	<0.001
Lt hip (%)	ΔAAHI=−0.75+0.20ΔLL	0.36	<0.001
ΔAAHI and ΔPT			
Rt hip (%)	ΔAAHI=3.4−0.26ΔPT	0.27	<0.01
Lt hip (%)	ΔAAHI=1.9−0.34ΔPT	0.36	<0.001
ΔAAHI and ΔSS			
Rt hip (%)	ΔAAHI=3.4+0.26ΔSS	0.28	<0.01
Lt hip (%)	ΔAAHI=2.3+0.31ΔSS	0.31	<0.001

Abbreviations: AAHI, anterior acetabular head index; LL, lumbar lordosis; PT, pelvic tilt; SS, sacral slope; VCA angle, ventral-central-acetabular angle.
Notes:
The parameters were evaluated through linear regression analysis.
Statistical significance was set at p<0.05.

tions are not expected to change significantly with this extensive fixation, the intraoperatively measured LL can be used to predict postoperative standing acetabular coverage. In patients with ASD patients with prior THA, especially in cases with large anterior cup coverage, the risk of dislocation due to postoperative over coverage requires that cup anteversion be adjusted within the target spinal parameters. Hence, this study may be particularly useful in setting target spinal parameters while accounting for cup anterior coverage in patients with prior THA.

Previous studies have reported a correlation between spinal sagittal balance and acetabular anteversion using the Lewinnek method with the coronal plane view via a formula[8)] and CT in the supine position[3)]. However, there are no reports directly evaluating the changes in the anterior coverage of the acetabulum in the standing position. Recently, reports have evaluated these changes using upright CT, which may be useful for providing detailed bone morphometry in the upright position[12)]; however, this imaging modality lacks versatility and can subject the patient to radiation exposure. In this regard, the false-profile view can be easily evaluated with a simple X-ray in the evaluation of standing acetabular coverage. Radcliff et al.[3)] reported that sagittal acetabular orientation correlates with spinopelvic balance and morphological traits. Buckland et al.[8)] investigated the influence of spinal realignment surgery on acetabular anteversion and found that acetabular anteversion was correlated with changes in spinal-pelvic parameters, with a sacral slope of 1.0° and a lumbar kyphosis of 3.2°, changing the acetabular anteversion by 1°. Our results showed that the VCA angle as a parameter of acetabular anteversion was correlated with a sacral slope of 3.2°-3.7° and lumbar lordosis (LL) of 5.2°-7.1°, changing the acetabular anteversion by 1°. This means that a 10° increase in LL will increase the VCA angle by 1.4°-1.9°, and a 40° increase in the intraoperative LL will result in an estimated 5.6°-7.6° increase in the VCA angle in the standing position postoperatively.

The VCA angle and AAHI on the false-profile view are recognized as valuable tools for the geometric assessment of anterior hip coverage in an upright position, with reported cutoff values for hip dysplasia of 25° and 84.1%, respectively[10)]. However, the safe range of VCA angles for THA dislocation in the false-profile view is not yet known. The safe anteversion range for the cup in the standing position in 107 THA patients with sagittal spinal deformity was reported to be 58%[13)]. Other reports have indicated that cup impingement in the sitting position is a risk factor for dislocation in patients with spinal-pelvic fusion after THA[14,15)]. In a report considering the forward impingement perspective, a safe zone with no hip instability was identified within 31°± 8° of operative anteversion[16)]. In our case, the mean postoperative PI-LL value was 2.5°, which is within a relatively good range for the spinopelvic parameters[2)], and the mean postoperative VCA angle was 32°. Therefore, in patients with ASD who had already undergone THA, the safe range of the VCA angle considering the spinopelvic parameters was suggested to be approximately 30°. Further evaluation of the present results in THA postoperative spine surgery will be conducted to determine whether the results will decrease dislocations.

It is important to acknowledge some limitations inherent in this study. Clinical outcomes, including the evaluation of the hip after ASD correction surgery, were not included to clarify the clinical relevance of the changes in the acetabular coverage parameters using the false-profile view. Si et al.[17)] reported that postoperative hip pain in adult patients with scoliosis following long-segment spinal fusion was notably linked to alterations in acetabular coverage and central edge angle. Moreover, the change in acetabular coverage was correlated with changes in LL in individuals who experienced hip pain after surgery. Because this was a study of how the correction of the spine by ASD surgery affects acetabular coverage, further investigation is needed to determine how the corrective fixation of the spine and acetabular coverage by this surgery affects quality of life. Second, hip and knee joint contractures are thought to significantly affect the position of the acetabulum in the standing position, but the range of motion of the lower extremities was not measured in this study, which may have included cases with lower extremity joint contractures. This could be because these patients may not achieve sufficient pelvic coverage after sagittal alignment correction. Lastly, because of the small size of the study group, it is possible that kyphosis alone and kyphoscoliosis were simultaneously present among some of the patients, and the localization of kyphosis was not classified. Compensation in the upper thoracic spine plays a crucial role in mitigating global malalignment, and compensation in the middle part of the thoracic spine is strongly correlated with LL in ASD patients[18)]. In the future, evaluation according to the location of kyphosis will be necessary.

An increased understanding of the relationships among these radiographic metrics can improve surgical planning for patients with a disease in both the hip and spine.

Conclusion

We described the relationship between the acetabular anteversion parameters obtained from a false-profile radiographic view and the spinal parameters with correction of ASD affecting activities of daily living. The false-profile view was effective in predicting how acetabular coverage changes in the standing position during extensive corrective fusion surgery, including pelvic fusion, in ASD.

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

Sources of Funding: None

Author Contributions: I.K. and H.T. designed the study; I.K., M.S., J.K., and T.O. performed the experiments and analyzed the data; H.T., T.K., and N.T. supervised the experiments; I.K. wrote the manuscript.

Ethical Approval: The study protocol was conducted in accordance with the Declaration of Helsinki and in compliance with the ethical guidelines for medical and health research involving human subjects and was approved by the ethics committee of Kagoshima University (approval code: 220270).

Informed Consent: Informed consent was obtained in the form of opt-out on the website.

References

1. Diebo BG, Shah NV, Boachie-Adjei O, et al. Adult spinal deformity. Lancet. 2019;394(10193):160-72.
2. 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.
3. Radcliff KE, Kepler CK, Hellman M, et al. Does spinal alignment influence acetabular orientation: a study of spinopelvic variables and sagittal acetabular version. Orthop Surg. 2014;6(1):15-22.
4. Luo Q, Kim YC, Kim KT, et al. Surgical correction for adult spinal deformity increases acetabular lateral coverage of femoral heads. BMC Musculoskelet Disord. 2021;22(1):988.
5. Abdel MP, von Roth P, Jennings MT, et al. What safe zone? The vast majority of dislocated THAs are within the lewinnek safe zone for acetabular component position. Clin Orthop Relat Res. 2016;474(2):386-91.
6. Dorr LD, Callaghan JJ. Death of the Lewinnek "safe zone". J Arthroplasty. 2019;34(1):1-2.
7. Furuhashi H, Yamato Y, Hoshino H, et al. Dislocation rate and its risk factors in total hip arthroplasty with concurrent extensive spinal corrective fusion with pelvic fixation for adult spinal deformity. Eur J Orthop Surg Traumatol. 2021;31(2):283-90.
8. Buckland AJ, Vigdorchik J, Schwab FJ, et al. Acetabular anteversion changes due to spinal deformity correction: bridging the gap between hip and spine surgeons. J Bone Joint Surg Am. 2015;97(23):1913-20.
9. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60(2):217-20.
10. Chosa E, Tajima N. Anterior acetabular head index of the hip on false-profile views. New index of anterior acetabular cover. J Bone Joint Surg Br. 2003;85(6):826-9.
11. Schwab F, Blondel B, Chay E, et al. The comprehensive anatomical spinal osteotomy classification. Neurosurgery. 2015;76(S1): S33-41.
12. Kikuchi S, Nakashima D, Yamada Y, et al. Relationship between hip joint proximity area and sagittal balance parameters: an upright computed tomography study. Eur Spine J. 2022;31(2):215-24.
13. DelSole EM, Vigdorchik JM, Schwarzkopf R, et al. Total hip arthroplasty in the spinal deformity population: does degree of sagittal deformity affect rates of safe zone placement, instability, or revision? J Arthroplasty. 2017;32(6):1910-7.
14. Furuhashi H, Togawa D, Koyama H, et al. Repeated posterior dislocation of total hip arthroplasty after spinal corrective long fusion with pelvic fixation. Eur Spine J. 2017;26(S1):100-6.
15. Yamato Y, Furuhashi H, Hasegawa T, et al. Simulation of implant impingement after spinal corrective fusion surgery in patients with previous total hip arthroplasty: a retrospective case series. Spine. 2021;46(8):512-9.
16. Murphy WS, Yun HH, Hayden B, et al. The safe zone range for cup anteversion is narrower than for inclination in THA. Clin Orthop Relat Res. 2018;476(2):325-35.
17. Si G, Li T, Liu X, et al. Correlation analysis between postoperative hip pain and spino-pelvic/hip parameters in adult scoliosis patients after long-segment spinal fusion. Eur Spine J. 2020;29(12): 2990-7.
18. Sato M, Uesugi M, Kawai T, et al. Upper thoracic compensation against global malalignment and spinopelvic mismatch in adult spinal deformity patients analyzed using the EOS imaging system. Spine Surg Relat Res. 2023;7(2):170-8.