European Spine Journal (2019) 28:2216–2222
https://doi.org/10.1007/s00586-019-06042-w

ORIGINAL ARTICLE

Residence could influence the surgical outcome after corrective surgery in adult spinal deformity: comparison study between urban and rural area in Korea

Un-Yong Choi[1] · Ji-In Kang[2] · Jeong-Yoon Park[2] · Sung-Uk Kuh[2] · Dong-Kyu Chin[2] · Keun-Su Kim[2] · Yong-Eun Cho[2] · Kyung-Hyun Kim[2]

Received: 25 November 2018 / Revised: 6 May 2019 / Accepted: 16 June 2019 / Published online: 24 June 2019

Abstract

Purpose Numerous factors affect the surgical outcomes in patients with adult spinal deformity (ASD). However, no study has examined the relationship between residence and physical factors and surgical outcomes in patients with ASD. Here, we analysed the impact of residence and physical factors on the post-operative outcomes of patients with ASD residing in urban (U) and rural (R) environments.

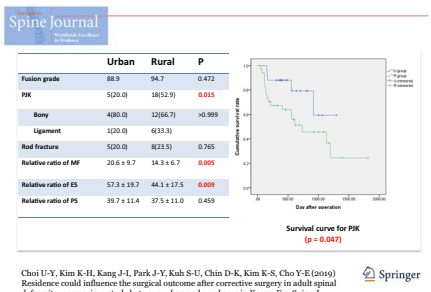
Methods We retrospectively reviewed data from patients who had undergone ASD surgery with sacropelvic fixation at a single institution between June 2011 and May 2017 with a minimum 1 year follow-up. We divided the patients into two groups (U and R). Preoperative demographic data were reviewed, and radiographic parameters were measured preoperatively, immediately postoperatively, at 1, 3, and 6 months, and at the final follow-up. The L4 axial paraspinal muscles were measured preoperatively using magnetic resonance imaging.

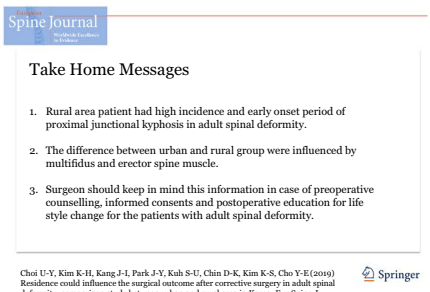
Results There were 25 and 34 patients in the U and R groups, respectively. Both groups had similar preoperative demographic and radiological parameters. There were no differences between the groups in post-operative radiographic parameters, clinical outcomes, and complications, but proximal junctional kyphosis (PJK) was significantly higher in the R group. Additionally, muscle mass in the multifidus and erector spinae was lower in the R than in the U group.

Conclusions Patient residence influenced PJK in patients with ASD. Mass reduction in the trunk extensor muscle is an important and existing risk factor for PJK. Surgeons should be aware of this information for preoperative counselling, informed consent, and post-operative education of patients with ASD.

Graphic abstract

These slides can be retrieved from Electronic Supplementary Material.





Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-019-06042-w) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Keywords Adult spinal deformity · Proximal junctional kyphosis · Urban living · Rural living · Trunk extensor muscle

Introduction

Adult spinal deformity (ASD) is becoming increasingly important as the population ages and quality of life is an issue of note. Numerous studies have been conducted with patients with ASD, and the importance of pelvic parameters and sagittal balance has been emphasized. The Scoliosis Research Society (SRS)–Schwab ASD classification [1, 2] uses sagittal modifiers such as pelvic tilt (PT), the sagittal vertical axis (SVA), and the mismatch between pelvic incidence and lumbar lordosis (PI-LL), based on radiographic alignment analysis, to determine thresholds used for treatment planning.

Nevertheless, ASD correction is challenging in spinal surgery due to the complexity of structural pathology and clinical presentation. Many factors affect the outcomes of surgery in patients with ASD, including the severity of deformity and imbalance, method of surgery, level of upper and lowest instrumented vertebra, instrument material, and patient factors [3–9].

Takemitsu et al. [10] studied community-based cohorts of patients with ASD and found that women living in rural areas showed severe histological atrophy in the back muscles and aggravated kyphosis during walking. These women were mostly farmers, and the causes of spinal deformity were overuse of the back muscles, repeated minor injuries, and increased compartmental pressure during prolonged bending postures.

Numerous studies with patients with adolescent idiopathic scoliosis (AIS) have found that lifestyle and residence affect post-operative quality of life [11, 12]. However, unlike AIS, no study has reported on the relationship between residence and physical factors and surgical outcomes in patients with ASD. The objective of this study was to analyse the impact of residence and physical factors on the post-operative outcomes of patients with ASD residing in urban (U) and rural (R) environments.

Patients and methods

Patient population

The institutional review board approved this study (IRB No. 3-2017-0371). We retrospectively reviewed consecutive patients with ASD with sacropelvic fusion by a single surgeon at a single centre between June 2011 and December 2017. We included patients with ASD with at least one of the following marked deformities of the sagittal modifier of the SRS-Schwab classification: mismatch between PI minus LL greater than 20°, SVA greater than 95 mm, PT greater than 30°. The area of residence was recorded when the patient was hospitalized for surgery. The U and R area categories were based on the OECD Urban Policy Reviews Korea 2012, patients residing in the 45 functional U areas classified in this book were included in the U group, and those residing in the remaining areas were included in the R group. The inclusion criteria for this study were age older than 18 years and a follow-up period of at least 1 year and the availability of appropriate imaging studies, such as whole spine radiography, computed tomography (CT), and magnetic resonance imaging, preoperatively and postoperatively. Patients who had undergone total sacrectomy were excluded from this study because reconstruction and operative invasiveness were likely to affect clinical and radiographic outcomes due to differences in biomechanical strength. Based on the criteria, the U group was composed of 25 patients and the R group of 35 patients. The diagnoses were lumbar degenerative kyphosis ($n=30$), iatrogenic flat back ($n=25$), post-traumatic kyphosis ($n=3$), and kyphosis due to spondylodiscitis ($n=1$).

Radiographic measurements

All subjects had 36-inch standing scoliosis radiographs for which the patients were not supported by external means such as walkers or hanging bars. Preoperative, immediate postoperative, 3-, 6-, and 12-month postoperative, and final follow-up anteroposterior and lateral radiographs were used to measure SVA, LL, PI, PT, sacral slope, thoracic kyphosis (TK), and cervical lordosis. Proximal junctional kyphosis (PJK) was defined as a "proximal junctional sagittal Cobb angle between the lower endplate of the uppermost instrumented vertebra and the upper endplate of the one supra-adjacent vertebrae and at least 10° greater than the preoperative measurement" [13]. Post-operative spine fusions were evaluated using the 4-point scale Bridwell fusion classification based on CT at 12 months postoperatively.

Spinal muscle assessments

MRI was performed using 1.5 Tesla equipment (MAGNETOM Avanto, Siemens, Munich, Germany). The patient was placed in the supine position with a foam wedge underneath the knees to maintain the hips and knees slightly flexed and a standardized lumbar position and symmetric alignment of the lower limbs. In the axial plane, the cross-sectional area (CSA) of the intervertebral disc, multifidus, erector spinae, and psoas major muscle was measured by drawing their

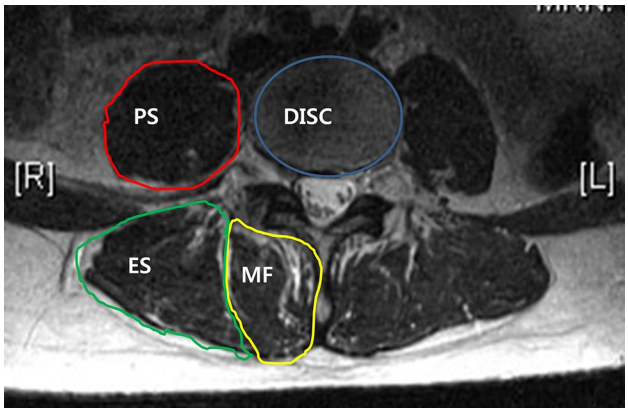


Fig. 1 Cross-sectional area of paraspinal muscles T2 axial images obtained at the L4/5 levels showing the lumbar paraspinal muscles. DISC: intervertebral disc; MF: multifidus; ES: erector spinae; PS: psoas muscle; and PJK: proximal

outline using the region of interest of the PACS program (Fig. 1, Centricity 3.0, General Electric Medical System, Milwaukee, WI, USA).

Fatty degeneration of the muscles was estimated according to the method of Ranson et al. [14] using a threshold of 120 for the greyscale to exclude the pixels representing fat content from each muscular CSA. The amount of fat was calculated by subtracting the muscle without the fat value from the total muscle value. The images were adjusted with image processing software (ImageJ, version 1.48, National Institutes of Health, Bethesda, Maryland, USA). Thereafter, we calculated the relative CSA, the ratio of CSA to the muscle of the disc, which was used to control the effects of body shape, weight, and height on the CSA of the muscle [15–17].

Post-operative management

Patients attempted to routinely stand and/or walk as often as possible on post-operative day 1. Subsequently, the patients were treated with a rehabilitation program through cooperation with the rehabilitation department and discharged within 3 weeks. The standard protocol of the rehabilitation program included progressive walking, as tolerated, with avoidance of squatting and bending at the waist. Patients were first followed up on an outpatient clinic basis and used a thoracolumbosacral orthosis for periods ranging from 1 to 2 months depending on each patient's status.

Statistical analysis

Data are presented as means ± standard deviations, unless specified otherwise. Intergroup comparisons of categorical variables were performed using the Chi-square test or Fisher's exact test. The unpaired t test was used to analyse parametric continuous variables. Moreover, the Mann–Whitney U test was used to analyse nonparametric continuous variables. Kaplan–Meier analysis was used to evaluate the timing and incidence of complications. All reported P values were two-sided, and $P < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS (IBM Corp., Armonk, NY, USA).

Result

Patient demographics

Regarding baseline characteristics, there were no statistically significant differences in age, sex, body mass index, follow-up period, bone mineral density, history of smoking, diabetes mellitus, hypertension, previous operations, and surgical diagnoses between the U group and the R group. Moreover, there were no significant differences in age > 55 years, osteopenia, and osteoporosis between the two groups (Table 1).

Operative results

Operatively, there were no statistically significant differences between the groups in terms of fusion levels (6.96 ± 2.90 vs. 7.73 ± 1.83, U group vs. R group; $P = 0.250$), operative time (440.84 ± 91.52 vs. 454.76 ± 117.94; $P = 0.625$), estimated blood loss (2470 ± 1854 vs. 2761 ± 1581; $P = 0.519$), intensive care unit stay period (1.48 ± 1.47 vs. 0.88 ± 1.14;

Table 1 Patient demographics

	Urban ($n = 25$)	Rural ($n = 34$)	P
Age	63.40 ± 14.11	66.64 ± 5.29	0.282
Age > 55	14 (56.0)	20 (58.8)	> 0.999
Male:female	5:20	5:29	0.729
BMI (kg/m2)	24.07 ± 3.35	23.80 ± 3.25	0.760
Follow-up (days)	616 ± 244	670 ± 265	0.571
BMD	− 2.15 ± 0.76	− 2.455 ± 1.09	0.302
Osteopenia	18 (97.7)	31 (93.9)	> 0.999
Osteoporosis	7 (36.8)	14 (42.4)	0.774
Previous surgery	15(60.0)	15(44.1)	0.295
HTN	13 (52.0)	15 (44.1)	0.605
DM	4 (16.0)	7 (20.6)	0.745
Smoking status	3 (12.0)	2 (5.9)	0.641
Diagnosis			0.139
Degenerative deformity	10 (40.0)	20 (58.8)	
Iatrogenic flat back	13 (52.0)	12 (35.3)	
Post-traumatic	1 (4.0)	2 (5.9)	
Infection	1 (4.0)	0	

BMI body mass index, *BMD* bone mineral density, *HTN* hypertension, and *DM* diabetes mellitus

$P = 0.099$), and rod construct count ($P = 0.300$). The score on the preoperative pain visual analogue scale (VAS) was higher in group U than in group R, but the pain VAS in both groups was significantly improved (Table 2).

Radiographic results

Large SVA difference (> 50 mm), large LL change (> 30°), preoperative TK + LL + PI (> 40°), large preoperative TK (> 40°), and fusion grade were not significantly different between the groups (Tables 3 and 4.) The complication profiles including rod fracture, reoperation rate, proximal junctional failure, surgical site infection, and screw fracture were not statistically significantly different between the groups. However, the incidence of PJK was significantly higher in the R group than in the U group (20% vs. 52.9%, U vs. R; $P = 0.015$). According to the Kaplan–Meier survival analysis, the mean time of the PJK was 859 days in the R group and 1018 in the U group, which was statistically significant ($P = 0.047$; Fig. 2). However, there were no differences in the bony and ligament types, which are PJK subtypes ($P > 0.999$)

Table 2 Operative outcomes

	Urban ($n = 25$)	Rural ($n = 34$)	P
Fusion level	6.96 ± 2.90	7.73 ± 1.86	0.250
OR time (minutes)	440.84 ± 91.52	454.76 ± 117.94	0.625
EBL (ml)	2470 ± 1854	2761 ± 1581	0.519
ICU stay (day)	1.48 ± 1.47	0.88 ± 1.14	0.099
Rod count			0.300
2	14 (56.0)	24 (70.6)	
3	5 (20.0)	7 (20.6)	
4	6 (24.0)	3 (8.8)	
VAS			
Preoperative	7.56 ± 1.53	6.41 ± 1.43	0.005
Postoperative	1.96 ± 1.62	1.88 ± 1.12	0.828
Difference	5.60 ± 1.93	4.52 ± 1.52	0.021

OR operating room, *EBL* estimated blood loss, *ICU* intensive care unit, and *VAS* visual analogue scale

Spinal muscle results

The CSA of the intervertebral disc and the erector spinae and psoas muscles and fat infiltration of the multifidus, erector spinae, and psoas muscles were not significantly different between the groups. The relative ratio (CSA of the muscle * fat infiltration/CSA of the intervertebral disc) of the multifidus and erector spinae was significantly higher in the R group than in the U group (Table 5). The CSA and relative ratio of the L4 erector spinae muscle were significantly lower in the PJK group than in the non-PJK group (Table 6).

Discussion

Spinal deformity in adults has a significant impact on health-related quality of life. As the general population continues to age and the elderly are living longer, the prevalence of ASD continues to increase. The prevalence of ASD in the general population is reported to range from 4 to 32% [18–20] and to be as high as 68% in the older population [1]. ASD has been studied with great interest over the past decade. The risk factors affecting outcome after corrective surgery for ASD include old age, sacropelvic screw type, large mismatch on SVA and LL, osteopenia, fusion to S1, and large TK [21].

In this study, the incidence of PJK was significantly higher in the R group than in the U group, and the timing of PJK onset was also earlier. There was no difference in the preoperative patient factors and sagittal imbalance between the two groups as well as intraoperative factors and radiological results after deformity correction surgery. This suggests that PJK is influenced not only by the existing factors but also by the patient's social factors such as post-operative lifestyle and living environment. In the

Table 3 Comparison of radiologic parameters outcomes

	Preoperative			Postoperative			Final follow-up		
	Urban	Rural	P	Urban	Rural	P	Urban	Rural	P
SVA	96.187 ± 78.130	109.750 ± 56.480	0.442	40.150 ± 54.569	29.968 ± 35.998	0.408	65.296 ± 59.516	66.033 ± 30.677	0.955
PI-LL	40.536 ± 26.529	48.688 ± 16.742	0.154	12.726 ± 11.866	10.961 ± 13.112	0.611	20.288 ± 15.649	21.121 ± 13.886	0.830
LL	15.468 ± 28.518	3.853 ± 16.779	0.077	41.917 ± 13.788	39.947 ± 13.908	0.605	35.076 ± 15.265	31.076 ± 14.371	0.308
SS	25.108 ± 14.444	18.735 ± 9.107	0.060	32.683 ± 12.698	29.209 ± 9.915	0.260	30.508 ± 10.649	24.891 ± 8.399	0.027
PT	30.912 ± 12.059	34.253 ± 11.218	0.284	22.226 ± 11.132	21.578 ± 10.195	0.824	25.024 ± 9.999	27.329 ± 10.176	0.390
PI	56.092 ± 17.486	52.588 ± 10.894	0.383	54.639 ± 17.101	50.972 ± 10.549	0.369	55.304 ± 17.399	52.215 ± 10.100	0.432
TK	20.456 ± 16.905	12.726 ± 10.194	0.050	23.187 ± 19.220	23.900 ± 11.275	0.863	28.204 ± 17.067	27.239 ± 13.406	0.809
CL	18.448 ± 14.964	17.518 ± 11.668	0.789	16.239 ± 11.632	11.119 ± 12.532	0.130	17.868 ± 15.341	17.838 ± 11.850	0.993

SVA sagittal vertical axis, *LL* lumbar lordosis, *SS* sacral slope, *PT* pelvic tilt, *PI* pelvic incidence, *TK* thoracic kyphosis, and *CL* cervical lordosis

Table 4 Characteristics radiographic measurements and complication between groups

	Urban ($n=25$)	Rural ($n=34$)	P
SVA difference > 50 mm	11 (47.8)	20 (62.5)	0.409
LL difference > 30°	11 (47.8)	18 (56.2)	0.592
Pre-TK + PI + LL > 40°	13 (52.0)	24 (70.6)	0.179
Preoperative TK > 40°	3 (12.0)	1 (2.9)	0.179
Fusion grade	88.9	94.7	0.472
I	6 (33.3)	10 (52.6)	
II	10 (55.6)	8 (42.1)	
III	2 (11.1)	1 (5.3)	
IV	0 (0)	0 (0)	
PJK	5 (20.0)	18 (52.9)	0.015
Bony	4 (80.0)	12 (66.7)	> 0.999
Ligament	1 (20.0)	6 (33.3)	
Rod fracture	5(20.0)	8 (23.5)	0.765
Reoperation	5 (20.0)	5 (14.7)	0.729
PJF	3 (12.0)	1 (2.9)	0.302
SSI	2 (8.0)	1(2.9)	0.569
Screw fracture	3 (12.0)	4 (11.8)	> 0.999

SVA sagittal vertical axis, *LL* lumbar lordosis, *TK* thoracic kyphosis, *PI* pelvic incidence, *CL* cervical lordosis, *PJF* proximal junctional failure, and *SSI* surgical site infection

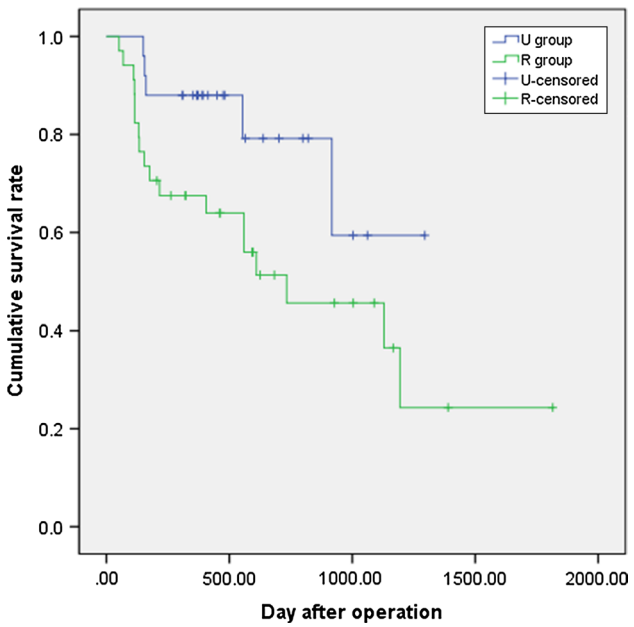


Fig. 2 Kaplan–Meier survival analysis curve for proximal junctional kyphosis was statistically different between the two groups. ($p=0.047$)

previous AIS studies [11, 22], social factors affected postoperative outcomes and patient quality of life. These studies also found that a U or R residence environment may influence the outcome and lifestyle of patients. Although other AIS-related studies [23] have not shown that lifestyle affects scoliosis in AIS, the AIS onset is in adolescence and degeneration has not progressed. ASD progressively worsens in old age [24], and lifestyle affects the disease.

In the R areas of Korea, the back muscles and constant flexion postures are frequently used while sitting on floor and during farming activities [25]. There have been studies [26, 27] showing that this lifestyle causes fatty changes in the back muscles and reduces extensor muscle strength. According to a biomechanical analysis by Le Huec et al., an anterior shifting of the centre of gravity increases the lever arm effect and easily damages the spine, which leads to compression fracture of the spine [28]. Constant flexion postures while sitting on floor and during farming activities increase the risk of PJK to the R group by moving the centre of gravity forward. Additionally, repeated flexion causes frequent stress on the upper instrumented vertebrae, causing PJK to develop and to occur earlier.

Table 5 Comparison of preoperative L4 axial muscle measurements

	Urban ($n=25$)	Rural ($n=34$)	P
CSA of the disc (mm^2)	2046.3 ± 293.0	2222.2 ± 383.1	0.060
CSA of the MF (mm^2)	519.2 ± 293.0	387.4 ± 176.7	0.013
Fat infiltration of MF	80.2 ± 19.6	81.5 ± 15.3	0.777
CSA of the ES (mm^2)	1310.5 ± 377.4	1172.0 ± 330.2	0.140
Fat infiltration of ES	86.9 ± 12.2	81.0 ± 14.8	0.115
CSA of the PS (mm^2)	815.3 ± 239.1	833.2 ± 268.5	0.792
Fat infiltration of PS	99.1 ± 2.2	99.1 ± 1.4	0.979
Relative ratio of MF	20.6 ± 9.7	14.3 ± 6.7	0.005
Relative ratio of ES	57.3 ± 19.7	44.1 ± 17.5	0.009
Relative ratio of PS	39.7 ± 11.4	37.5 ± 11.0	0.459

CSA cross-sectional area, *MF* multifidus, *ES* erector spinae, and *PS* psoas muscle

Table 6 PJK vs. non-PJK

	PJK ($n=23$)	Non-PJK ($n=36$)	P
CSA of the disc (mm2)	2186.9 ± 368.9	2122.6 ± 350.5	0.503
CSA of the MF	397.5 ± 209.7	472.4 ± 199.1	0.173
Fat infiltration of MF	81.7 ± 15.0	80.5 ± 18.8	0.785
CSA of the ES	1111.1 ± 313.8	1307.2 ± 362.0	0.037
Fat infiltration of ES	82.0 ± 13.8	84.4 ± 14.1	0.519
CSA of the PS	792.0 ± 252.2	847.0 ± 257.1	0.423
Fat infiltration of PS	99.1 ± 1.3	99.1 ± 2.0	0.937
Relative ratio of MF	15.2 ± 8.7	18.0 ± 8.6	0.225
Relative ratio of ES	43.4 ± 18.3	53.7 ± 19.4	0.047
Relative ratio of PS	36.1 ± 10.4	40.0 ± 11.4	0.188

CSA cross-sectional area, *MF* multifidus, *ES* erector spinae, *PS* psoas muscle, and *PJK* proximal junctional kyphosis

Kobayashi et al. reported a motion relationship between trunk flexor strength and extensor strength [27]. They reviewed lumbar degenerative kyphosis, which is a sagittal imbalance associated with reduced extensor muscle strength by 22%, active ROM by 55%, passive ROM by 13%, and increased ambulatory kyphosis by 117%. In the current study, the relative ratios of trunk extensor muscle group (multifidus and erector spinae muscles) in the R group were statistically significantly different from those in the U group, but the psoas muscle was no difference. In the PJK group and the non-PJK group, the relative ratio of the erector spinae muscle showed a significantly smaller value in the PJK group. These results suggest that the deterioration of the trunk extensor muscle in the R group may have affected the occurrence and timing of PJK.

This study has several limitations. First, it is limited by its single-centre design, retrospective nature, and the relatively small sample size. Second, although the patients were categorized according to the area where they lived, the questionnaire did not quantify patient lifestyle. Finally, the amount of muscle mass was not measured in the whole body but in the L4 axial cross section. The L4 axial CSA could not represent whole muscle mass, but the relative ratio was measured using intervertebral disc CSA to control this problem. As such, the results of this study warrant the need for larger prospective, multicentre studies to further extrapolate them to future patient care.

Conclusion

The current study showed that the R group had higher incidence and earlier onset of PJK than did the U group. Reduction in the muscle mass of the trunk extensor muscle is an important factor in the incidence and occurrence, as well as an existing risk factor for PJK. These factors may help explain the higher incidence of PJK among rural dwellers and provide direction on how post-operative complication prevention and management strategies could be tailored to meet the needs of patient with muscle mass reduction.

Funding This work was supported by the World Class 300 Project (R&D) (S2482672) of the MOTIE, MSS (Korea).

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

References

1. Schwab F, Ungar B, Blondel B, Buchowski J, Coe J, Deinlein D, DeWald C, Mehdian H, Shaffrey C, Tribus C, Lafage V (2012) Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine (Phila Pa 1976) 37(12):1077–1082. https://doi.org/10.1097/brs.0b013e31823e15e2
2. Bess S, Schwab F, Lafage V, Shaffrey CI, Ames CP (2013) Classifications for adult spinal deformity and use of the scoliosis research society-schwab adult spinal deformity classification. Neurosurg Clin N Am 24(2):185–193. https://doi.org/10.1016/j.nec.2012.12.008
3. Kim YJ, Lenke LG, Bridwell KH, Kim J, Cho SK, Cheh G, Yoon J (2007) Proximal junctional kyphosis in adolescent idiopathic scoliosis after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. Spine (Phila Pa 1976) 32(24):2731–2738. https://doi.org/10.1097/brs.0b013e31815a7ead
4. Kim YJ, Bridwell KH, Lenke LG, Glattes CR, Rhim S, Cheh G (2008) Proximal junctional kyphosis in adult spinal deformity after segmental posterior spinal instrumentation and fusion: minimum five-year follow-up. Spine (Phila Pa 1976) 33(20):2179–2184. https://doi.org/10.1097/brs.0b013e31817c0428
5. Denis F, Sun EC, Winter RB (2009) Incidence and risk factors for proximal and distal junctional kyphosis following surgical treatment for Scheuermann kyphosis: minimum five-year follow-up. Spine (Phila Pa 1976) 34(20):E729–E734. https://doi.org/10.1097/brs.0b013e3181ae2ab2
6. Hyun SJ, Rhim SC (2010) Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients: a long-term follow-up data. J Korean Neurosurg Soc 47(2):95–101. https://doi.org/10.3340/jkns.2010.47.2.95
7. Yagi M, Akilah KB, Boachie-Adjei O (2011) Incidence, risk factors and classification of proximal junctional kyphosis: surgical outcomes review of adult idiopathic scoliosis. Spine (Phila Pa 1976) 36(1):E60–E68. https://doi.org/10.1097/brs.0b013e3181eeaee2
8. Ha Y, Maruo K, Racine L, Schairer WW, Hu SS, Deviren V, Burch S, Tay B, Chou D, Mummaneni PV, Ames CP, Berven SH (2013) Proximal junctional kyphosis and clinical outcomes in adult spinal deformity surgery with fusion from the thoracic spine to the sacrum: a comparison of proximal and distal upper instrumented vertebrae. J Neurosurg Spine 19(3):360–369. https://doi.org/10.3171/2013.5.SPINE12737
9. Liu FY, Wang T, Yang SD, Wang H, Yang DL, Ding WY (2016) Incidence and risk factors for proximal junctional kyphosis: a meta-analysis. Eur Spine J 25(8):2376–2383. https://doi.org/10.1007/s00586-016-4534-0
10. Takemitsu Y, Harada Y, Iwahara T, Miyamoto M, Miyatake Y (1988) Lumbar degenerative kyphosis Clinical, radiological and epidemiological studies. Spine (Phila Pa 1976) 13(11):1317–1326
11. Wang C, Xu W, He S, Gu S, Zhao Y, Zhang J, Zhu X, Li M (2010) Differences in postoperative quality of life between adolescent patients with idiopathic scoliosis residing in urban and rural environments. Spine (Phila Pa 1976) 35(6):652–656. https://doi.org/10.1097/brs.0b013e3181b9fe3e
12. Misterska E, Glowacki M, Panek S, Ignys-O'Byrne A, Glowacki J, Ignys I, Krauss H, Piatek J (2012) Effects of living environment on the postoperative scoliosis research society-24 results in females with adolescent idiopathic scoliosis. Med Sci Monit 18(8):CR523–CR531
13. Cho SK, Shin JI, Kim YJ (2014) Proximal junctional kyphosis following adult spinal deformity surgery. Eur Spine J 23(12):2726–2736. https://doi.org/10.1007/s00586-014-3531-4
14. Ranson CA, Burnett AF, Kerslake R, Batt ME, O'Sullivan PB (2006) An investigation into the use of MR imaging to determine the functional cross sectional area of lumbar paraspinal muscles. Eur Spine J 15(6):764–773. https://doi.org/10.1007/s00586-005-0909-3

15. Lee HJ, Lim WH, Park JW, Kwon BS, Ryu KH, Lee JH, Park YG (2012) The relationship between cross sectional area and strength of back muscles in patients with chronic low back pain. Ann Rehabil Med 36(2):173–181. https://doi.org/10.5535/arm.2012.36.2.173
16. Chen YY, Pao JL, Liaw CK, Hsu WL, Yang RS (2014) Image changes of paraspinal muscles and clinical correlations in patients with unilateral lumbar spinal stenosis. Eur Spine J 23(5):999–1006. https://doi.org/10.1007/s00586-013-3148-z
17. Kim JY, Ryu DS, Paik HK, Ahn SS, Kang MS, Kim KH, Park JY, Chin DK, Kim KS, Cho YE, Kuh SU (2016) Paraspinal muscle, facet joint, and disc problems: risk factors for adjacent segment degeneration after lumbar fusion. Spine J 16(7):867–875. https://doi.org/10.1016/j.spinee.2016.03.010
18. Kostuik JP, Bentivoglio J (1981) The incidence of low-back pain in adult scoliosis. Spine 6(3):268–273
19. Carter OD, Haynes SG (1987) Prevalence rates for scoliosis in US adults: results from the first national health and nutrition examination survey. Int J Epidemiol 16(4):537–544
20. Liu G, Tan JH, Ee G, Chan YH, Low SL, Wong HK (2016) Morphology and prevalence study of lumbar scoliosis in 7,075 multiracial asian adults. J Bone Joint Surg Am 98(15):1307–1312. https://doi.org/10.2106/JBJS.15.00710
21. Kim JS, Phan K, Cheung ZB, Lee N, Vargas L, Arvind V, Merrill RK, Gidumal S, Di Capua J, Overley S, Dowdell J, Cho SK (2019) Surgical, radiographic, and patient-related risk factors for proximal junctional kyphosis: a meta-analysis. Global Spine J 9(1):32–40. https://doi.org/10.1177/2192568218761362
22. Kahanovitz N, Weiser S (1989) The psychological impact of idiopathic scoliosis on the adolescent female. A preliminary multicenter study. Spine (Phila Pa 1976) 14(5):483–485
23. Watanabe K, Michikawa T, Yonezawa I, Takaso M, Minami S, Soshi S, Tsuji T, Okada E, Abe K, Takahashi M, Asakura K, Nishiwaki Y, Matsumoto M (2017) Physical activities and lifestyle factors related to adolescent idiopathic scoliosis. J Bone Joint Surg Am 99(4):284–294. https://doi.org/10.2106/JBJS.16.00459
24. Ames CP, Scheer JK, Lafage V, Smith JS, Bess S, Berven SH, Mundis GM, Sethi RK, Deinlein DA, Coe JD, Hey LA, Daubs MD (2016) Adult spinal deformity: epidemiology, health impact, evaluation, and management. Spine Deform 4(4):310–322. https://doi.org/10.1016/j.jspd.2015.12.009
25. Lee CH, Chung CK, Jang JS, Kim SM, Chin DK, Lee JK (2017) Lumbar degenerative kyphosis is not byword for degenerative sagittal imbalance: time to replace a misconception. J Korean Neurosurg Soc 60(2):125–129. https://doi.org/10.3340/jkns.2016.0607.001
26. Lee SH, Kim KT, Suk KS, Lee JH, Seo EM, Huh DS (2011) Sagittal decompensation after corrective osteotomy for lumbar degenerative kyphosis: classification and risk factors. Spine (Phila Pa 1976) 36(8):E538–E544. https://doi.org/10.1097/brs.0b013e3181f45a17
27. Kobayashi T, Chiba H, Jimbo S, Senoo I, Shimizu M, Atsuta Y, Ito H, Sugisawa H, Sugawara T, Habaguchi T (2016) Clinical, physical, and radiographic analyses of lumbar degenerative kyphosis and spondylolisthesis among community-based cohort. Eur Spine J 25(8):2384–2389. https://doi.org/10.1007/s00586-016-4615-0
28. Le Huec JC, Richards J, Tsoupras A, Price R, Leglise A, Faundez AA (2018) The mechanism in junctional failure of thoraco-lumbar fusions. Part I: biomechanical analysis of mechanisms responsible of vertebral overstress and description of the cervical inclination angle (CIA). Eur Spine J 27:129–138. https://doi.org/10.1007/s00586-017-5425-8

Affiliations

Un-Yong Choi[1] · Ji-In Kang[2] · Jeong-Yoon Park[2] · Sung-Uk Kuh[2] · Dong-Kyu Chin[2] · Keun-Su Kim[2] · Yong-Eun Cho[2] · Kyung-Hyun Kim[2]

✉ Kyung-Hyun Kim
nskhk@yuhs.ac

[1] Department of Neurosurgery, CHA Bundang Medical Center, CHA University School of Medicine, Gyeonggi-do, Seongnam-Si 13496, Republic of Korea

[2] Department of Neurosurgery, Gangnam Severance Hospital, Spine and Spinal Cord Institute, Yonsei University College of Medicine, 211 Eonjuro Gangnam-gu, Seoul 135-720, South Korea