Incidence and Risk Factors of Proximal Junctional Kyphosis in Elderly Patients Over 65 Years of Age with Degenerative Spinal Diseases

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Research article

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Abstract

Background. The mechanisms and risk factors for proximal junctional kyphosis of elderly patients may differ from those of non-elderly patients. The risk factors for PJK in the elderly population remain unclear.

Methods. The present study enrolled elderly DSD patients over 65 years of age who underwent thoracolumbar fusion with no less than 3 levels fused. All patients underwent CT and MRI scans preoperatively, and full spine standing X-ray preoperatively, postoperatively and during follow-up with a minimum follow-up of 18 month. Paraspinal muscle cross-sectional area(CSA) and paraspinal muscle fatty infiltration(FI) of erector spinae(ES) and multifidus muscle(MF), LL, PI, PT, SS, PI-LL and vertebra CT HU value were measured. Radiological PJK was defined as a sagittal Cobb angle between the UIV and the two levels above the UIV (UIV+2) of 10° or greater and at least 10° greater than the preoperative measurement. Parameters were compared between PJK and Non-PJK patients.

Result. A total of 259 patients were enrolled. The prevalence of PJK was 35.9%. Compared with Non-PJK group, PJK group had significantly older age at surgery, greater BMI, lower vertebra CT value and greater PI and a larger PI-LL mismatch. Both erector spinae(ES) and multifidus muscle(MF) relative cross-sectional area(rCSA) of PJK patients were significantly smaller, the ES and MF fatty infiltration(FI) were significantly greater than the Non-PJK patients. Older age at surgery, greater BMI, greater PI, smaller MF rCSA, greater ES and MF FI and smaller CT value were independent risk factors for PJK in elderly patient population.

Conclusions. For elderly patients with DSD, PJK is a commonly seen complication. Higher age at surgery, larger BMI, significant paraspinal muscle degeneration and low bone mineral density are risk factors for PJK. Appropriate preoperative and postoperative measures are beneficial for reducing the risk of PJK in the elderly.

Background

As population aging became a significant tendency among the globe, degenerative spinal diseases (DSD) are now accounted for a large part of medical expenditure. Spinal fixation and fusion is a standard method for the treatment of DSD. For multi-segment spinal fusion patients, proximal junctional kyphosis (PJK) is a postoperative adjacent segment complication and commonly seen in deformity correction cases[1]. Glattes et al. first defined PJK as a proximal junctional sagittal Cobb angle between the lower endplate of uppermost instrumented vertebra (UIV) and the upper endplate of 2 supra-adjacent vertebra 10° or more and at least 10° greater than the preoperative measurement[2]. Other definitions include a proximal junctional sagittal Cobb angle between the UIV and UIV + 2 of 20° or more and a postoperative sagittal Cobb angle increase of 15° or more between the UIV and UIV + 1. The incidence of PJK ranges from 5–46%, two third of which occur within 3 months after surgery and 80% of cases occur within 18 months after surgery[3]. PJK results in poor surgical outcome due to pain, deformity, instability, disability,

and potential neurologic deficits. Especially in elderly patients, due to the deterioration of spinal compensative capacity, the incidence and severity of PJK are higher than those in non-elderly patients[4].

As PJK leads to poor clinical prognosis and higher treatment costs, more clinical attention has been paid to the prevention of PJK. A variety of risk factors have been shown to be related to the occurrence of PJK, including surgical, radiological, anatomical and patient-related factors. For elderly patients, different radiological, anatomical and demographic parameters may lead to different mechanisms and risk factors for PJK from those of non-elderly patients. The risk factors for PJK in the elderly population remain unclear. Therefore, the purpose of this study is to analyze the incidence and risk factors for PJK in a cohort of elderly DSD patients.

Methods

Patients

This study has been approved by the Center's Medical Ethics Committee. The patient hospitalization number were used to encode demographic information and surgical data of the subjects. All parties are fully aware of the confidentiality of the Helsinki Declaration. The informed consent was waived as this was a retrospective study.

Our retrospective study reviewed elderly patients over 65 years of age with DSD diagnosed and treated at our center from January 2016 to April 2019. Patients who underwent thoracolumbar fusion with no less than 3 levels fused were included. All patients underwent CT and MRI scans of the corresponding spinal area preoperatively, and full spine standing X-ray preoperatively, postoperatively and during follow-up. A minimum 18 month follow-up was required. Exclusion criteria include neuromuscular diseases, spinal infections, ankylosing spondylitis, spinal tumor and previous spinal trauma or surgery.

Parameters

The image data of all patients were collected and measured through the hospital's built-in Picture Archiving and Communication System (PACS). Spinal and pelvic parameters on full spine standing X-ray includes LL, PI, PT, SS and PI-LL. Radiological PJK was defined as a sagittal Cobb angle between the UIV and the two levels above the UIV (UIV + 2) of 10° or greater and at least 10° greater than the preoperative measurement[2]. Patients were divided into two groups according to the occurrence of PJK.

The paraspinal muscle cross-sectional area(CSA) measurement used the middle layer of the MRI on L1/L2 segment. And adopted gray-scale discrimination method proposed by Ranson et al.[5]. CSA of erector spinae(ES) and multifidus muscle(MF) was obtained by dividing the ROI according to the boundaries of each paraspinal muscle on the cross section. Relative cross-sectional area (rCSA) was adopted to eliminate the individual differences in muscle volume that affect the results[6]. rCSA is the ratio of the paraspinal muscle CSA to the CSA of the vertebra of the same segment. The mean value of

both sides was measured and adopted for analysis. To measure the degree of paraspinal muscles fatty infiltration(FI), we defined the middle layer of the MR image as the measurement plane of the segment, and used the Image J Threshold method (National Institutes of Health, Bethesda, MD, USA). Namely the percentage of the number of fat pixels in the total number of pixels in each paraspinal muscle ROI[7]. A threshold gray-scale value of 120 was used to distinguish the pixels of intramuscular fatty tissue[8]. The measurement method is shown in Fig. 1.

CT HU value was measured on preoperative lumbar CT scans by dividing the region of interest (ROI) over an axial image of vertebral mid-body from L1 to L4. Average HU value of ROI was used to represent the bone density of each vertebra. And mean value of L1-L4 vertebra was used for analysis[9, 10].

All parameters were measured respectively by two orthopedic surgeons receive radiological training. Mean value of the two measurements was adopted for analysis.

Statistical Analysis

Statistical analysis was conducted with SPSS 22.0 (IBM Corp., USA). Student t test and Chi-square test were conducted for comparison of parameters between two groups. Binary logistic regression analysis was used to identify the independent risk factors for PJK. Intra-observer reliability and the inter-observer reliability were evaluated using the intraclass correlation coefficient (ICC)[11]. ICCs less than ± 0.40 indicate poor, ± 0.40– 0.75 indicate fair or good, and ± 0.75–1.00 indicate excellent reliability[12]. The data is presented as mean values ± standard deviation. $P < 0.05$ was considered to be statistically significant.

Results

Patient demographics

A total of 1487 patients underwent spinal fusion during the period examined. Among them, 259 patients met the inclusion criteria and obtained sufficient follow-up. The average follow-up time was 22.8 months (range 18–58 months). The prevalence of PJK was 35.9% (n = 93). Compared with Non-PJK group, PJK group had significantly older age at surgery, greater BMI and lower vertebra CT value. Patient demographics were summarized in Table 1.

Table 1
Patient demographics of PJK and Non-PJK group

	PJK	Non-PJK	P-Values
Number of patients	93	166	
Age (yrs.)	74.2 ± 6.2	71.2 ± 4.5	< 0.001
Female	66	106	0.245
History of smoking	12	26	0.547
BMI	26.90 ± 3.37	25.82 ± 3.74	0.021
CT value (HU)	102.0 ± 38.3	114.3 ± 31.0	0.009
BMI body mass index, HU hounsfield unit. All values are expressed as mean value ± standard deviation.			

Preoperative Parameters

We compared preoperative radiological and muscular parameters between the two groups. PJK group showed a larger PI and a larger PI-LL mismatch. Muscular parameters were found significantly different between the two groups. Both ES and MF rCSA of PJK patients were significantly smaller than the other group, the ES and MF FI were significantly greater than the other group. There was no significant difference in LL, PT, SS and levels fused between the two groups. The intra-observer and inter-observer reliability were excellent in measurements for muscle rCSA and FI (ICCs were above 0.8). The preoperative parameters were summarized in Table 2.

Table 2
Comparison of preoperative parameters between PJK and Non-PJK patients

	PJK	Non-PJK	P-Values
Number of patients	93	166	
Levels fused	4.4 ± 1.8	4.1 ± 1.3	0.158
UIV			
Thoracic	33	45	
Lumbar	60	121	0.159
LL	29.9 ± 9.5	30.8 ± 9.1	0.483
PI	58.1 ± 4.6	56.3 ± 5.7	0.005
PT	39.4 ± 10.0	41.0 ± 10.4	0.218
SS	19.5 ± 10.8	17.9 ± 12.2	0.282
|PI-LL|	18.6 ± 9.4	16.2 ± 9.1	0.043
rCSA-ES	109.6 ± 24.3	120.6 ± 37.9	0.005
rCSA-MF	31.0 ± 12.3	40.9 ± 28.1	0.001
FI-ES	47.2 ± 8.0%	40.3 ± 9.2%	< 0.001
FI-MF	60.2 ± 7.9%	58.2 ± 6.9%	0.034

UIV uppermost instrumented vertebra, LL lumbar lordosis, PI pelvic incidence, PT pelvic tilt, SS sacral slope, rCSA relative paraspinal muscle cross area, FI fatty infiltration, MF multifidus muscle, ES erector spinae. All values are expressed as mean value ± standard deviation.

Table 3
Binary logistic regression of risk factors for PJK

	OR	95% CI	P-Values
Age	1.134	1.066–1.207	< 0.001
BMI	1.139	1.038–1.250	0.006
PI	1.086	1.011–1.168	0.025
|PI-LL|	1.011	0.972–1.052	0.587
rCSA-ES	0.995	0.985–1.005	0.320
rCSA-MF	0.972	0.955–0.989	0.002
FI-ES	1.092	1.051–1.134	< 0.001
FI-MF	1.064	1.013–1.118	0.013
CT value (HU)	0.991	0.981-1.000	0.050

BMI body mass index, PI pelvic incidence, LL lumbar lordosis, rCSA relative paraspinal muscle cross area, FI fatty infiltration, MF multifidus muscle, ES erector spinae, HU hounsfield unit.

Risk Factors

Binary logistic regression analysis were conducted to identify the independent risk factors for PJK. The result indicated older age at surgery (Odds Ratio(OR) = 1.134, 95% confidence interval(CI) = 1.066–1.207, p < 0.001), greater BMI (OR = 1.139, 95% CI = 1.038–1.250, p = 0.006), greater PI (OR = 1.086, 95% CI = 1.011–1.168, p = 0.025), smaller MF rCSA (OR = 0.972, 95% CI = 0.955–0.989, p = 0.002), greater ES and MF FI (OR = 1.092, 95% CI = 1.051–1.134, p < 0.001; OR = 1.064, 95% CI = 1.013–1.118, p = 0.013) and smaller CT value (OR = 0.991, 95% CI = 0.981-1.000, p = 0.050) were independent risk factors for PJK in elderly patient population.

Discussion

Our data showed that among 259 elderly patients, the incidence of PJK was 35.9%. Higher age at surgery, larger BMI, significant paraspinal muscle degeneration and poor bone mineral density made DSD patients susceptible to PJK. To our knowledge, this is the first study of PJK risk factors in a large number of elderly patients with DSD.

Anatomical, surgical, radiological and patient-related factors are all involved in the incidence of PJK. Age has been proven to be associated with the incidence of PJK[13, 14]. Age at surgery over 55 is shown to be an independent risk factor for PJK, which is considered to be related to age dependent disc, facet joint and paraspinal muscle degeneration[15]. These degenerative changes are commonly seen in elderly DSD

patients over 65 years of age. While greater age was still shown to be an independent risk factor for PJK. In our point of view, greater age brings worse preoperative reserve capacity and postoperative compensatory capacity. Therefore, for DSD elderly patients over 65 years of age, perioperative management is one of the key steps to decrease the risk of PJK. Preoperative evaluation and nutritional support by geriatricians can reduces the incidence of postoperative complications, shortens the duration of in-hospital stay, and contributes to improved perioperative functional status in elderly population[16]. Comprehensive perioperative management such as Enhanced Recovery After Surgery(ERAS) can reduce traumatic impact and accelerate postoperative recovery of patients[17]. Early rehabilitation and functional exercise can accelerate the recovery of paraspinal muscles and reduce the adverse effects of advanced age.

Osseous and soft-tissue failure are the two main pathological changes of PJK[3, 18]. The bone quality and quantity of UIV is closely related to the occurrence of PJK[19, 20]. Fixation failure of UIV and compression fractures of UIV and UIV + 1 are common manifestations of PJK. These osseous failures often lead to clinical symptoms and require surgical intervention. Enhancement techniques such as vertebroplasty at UIV and UIV + 1 have been shown to be a protective factor[21]. Osteopenia and osteoporosis are commonly seen conditions in the elderly, especially for female population. Looker et al. reported a 11% of osteoporosis rate in elderly Americans[22]. Johnston et al. estimated osteoporosis affected one-fifth of women aged 70[23]. The higher osteoporosis rate in the elderly population increases the risk of PJK in DSD patients. Therefore, we recognize the importance of regular anti-osteoporosis treatment in elderly DSD patients. The use of bisphosphonates or biosynthetic parathyroid hormone combined with calcium and vitamin D can effectively maintain the bone quality of elderly patients[24]. Regular anti-osteoporosis treatment could be a momentous factor in preventing mechanical complications including PJK.

Paraspinal muscles have been shown to be an important stabilizer of the spine [25, 26]. Our data regarding patients over 65 years of age indicated both ES and MF degeneration to be risk factors for PJK. These results are consistent with previous studies[15]. As the main components of the posterior spine extensor, ES and MF provide stability to maintain the overall and local sagittal balance of the spine[27, 28]. Paraspinal muscle degeneration caused by aging is commonly seen in elderly population[29]. The weakening of the protective effect of paraspinal muscles increases the risk of PJK. For elderly patients, appropriate surgical techniques can be adopted on the basis of appropriate radiological evaluation to protect the vertebra, ligaments and paraspinal muscles, along with continuous anti-osteoporosis treatment and muscle rehabilitation to reduce the risk of PJK[30]. Appropriate preventive measures are important in reducing the risk of PJK, especially for elderly patients.

Several limitations of our study should be considered. Firstly, this was a retrospective, single-institution study and the result may reflect biases. Secondly, since not all of DSD patients had underwent thoracic MRI, we chose L1/L2 segment as the measurement level of paraspinal muscles. Although the paraspinal muscle degeneration shows consistency between different levels, the L1/L2 level parameters cannot fully

represent the state of the paraspinal muscles of the UIV level[31]. Moreover, our data were based on radiological findings, which did not reflect clinical outcomes directly.

Conclusions

For elderly patients with DSD, PJK is a commonly seen complication. Higher age at surgery, larger BMI, significant paraspinal muscle degeneration and low bone mineral density are risk factors for PJK. Appropriate preoperative and postoperative measures are beneficial for reducing the risk of PJK in the elderly.

Declarations

Ethics approval and consent to participate

This study has been approved by the Medical Ethics Committee of Xuanwu hospital of Capital Medical University, China. All parties are fully aware of the confidentiality of the Helsinki Declaration. The informed consent was waived as this was a retrospective study.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Junzhe Ding performed literature search and was a major contributor manuscript writing. Chao Kong reviewed the manuscript and contributed equally in manuscript writing. All authors read and approved the final manuscript.

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Figures

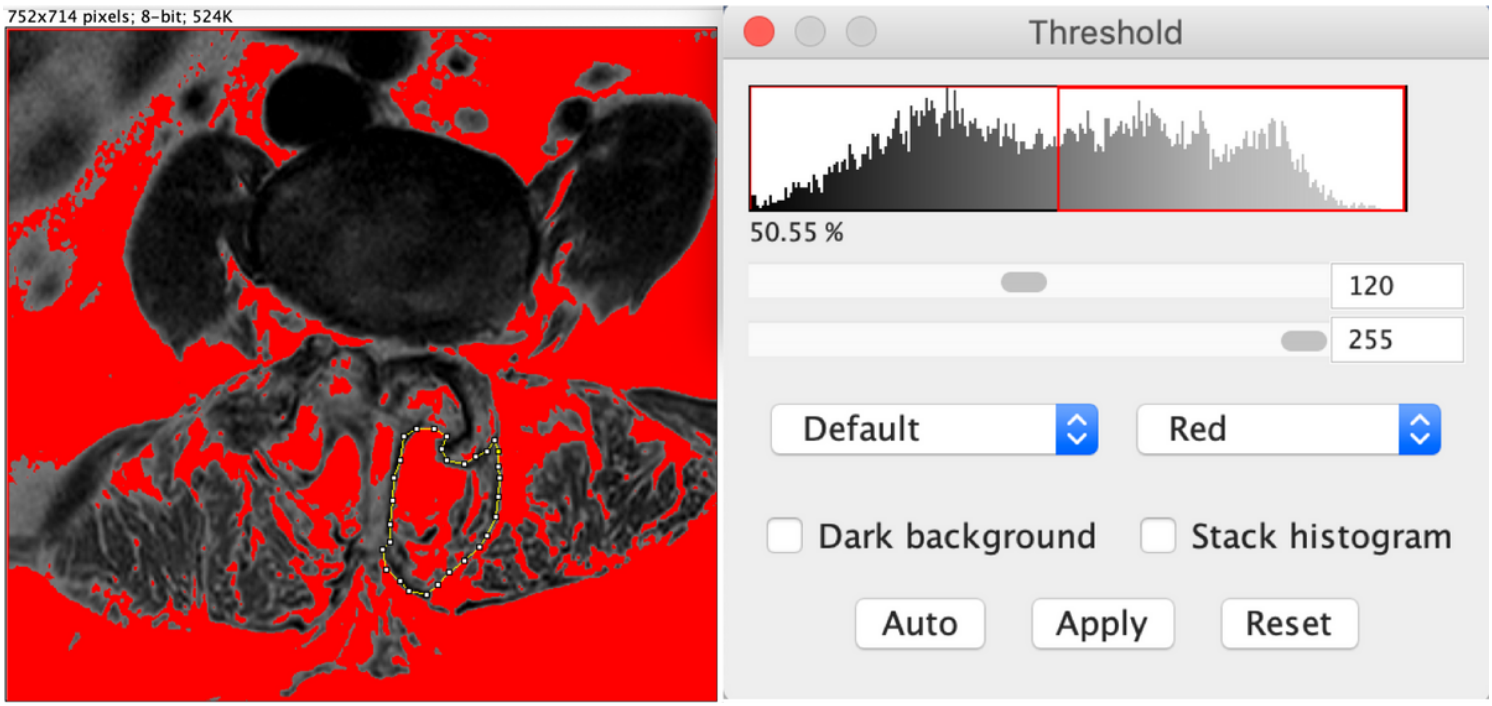

Figure 1

Measurement method of the multifidus muscle fatty infiltration. The Image J Threshold method on the middle layer of magnetic resonance image in each segment.