RISK FACTORS FOR PROXIMAL JUNCTIONAL KYPHOSIS IN IDIOPATHIC SCOLIOSIS SURGERY*

A.Yu. Sergunin, M.V. Mikhailovsky, A.N. Sorokin
Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Russia

Objective. To identify risk factors for development of proximal junctional kyphosis (PJK) in patients with idiopathic scoliosis operated on using segmental posterior spinal instrumentation.
Material and Methods. Radiographs of 95 patients with idiopathic scoliosis operated on using segmental posterior spinal instrumentation were analyzed. Preoperative and postoperative spondylograms and images taken at the end of the second year of follow-up were evaluated. The PJK was defined as 10° or more increase in the angle of kyphosis between the caudal endplate of the upper instrumented vertebra and the cephalad endplate of two adjacent proximal vertebrae as compared with preoperative angle at the same level.
Results. The prevalence of PJK at the end of the second year of follow-up was 24%. Before surgery the average value of the proximal transition angle was 6.7° ± 5.4° in patients with PJK (Group I) and 6.1° ± 4.6° in patients who have not developed PJK (Group II). Within two weeks after the surgery, the angle increased to 15.0° ± 6.7° in Group I patients and to 6.9° ± 4.4° in Group II patients. Two years after the surgery the angle was 23.0° ± 6.0° and 8.4° ± 5.6°, in Group I and II, respectively.
Conclusion. Statistically significant risk factors were initial hyperkyphosis of the thoracic spine (>40°), significant change in thoracic kyphosis in the postoperative period, initial value of the proximal transition angle, distal location of the upper instrumented vertebra, and the use of hybrid fixation.
Key Words: surgical treatment, proximal junctional kyphosis, risk factors, idiopathic scoliosis.

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Nowadays, a large number of publications is devoted to proximal junctional kyphosis (PJK). One of the first articles on the topic was the paper by Lee et al. [11], which analyzed long-term surgical treatment outcomes with follow-up period of at least two years in 69 patients with idiopathic scoliosis operated on using segmental instrumentation. The authors defined junctional kyphosis as increase of 5° or more in kyphosis angle between the upper instrumented vertebra and the superjacent vertebrae, compared to preoperative radiographs. Proximal junctional kyphosis was detected in 32 (46 %) patients. In the subsequent years, the authors have tried to identify risk factors and evaluate quantitative parameters of PJK. In their work, Glattes et al. [5] remarked that a case of PJK should be defined as junctional kyphosis greater than or equal to 10° compared to the preoperative period. We failed to find any paper devoted to the issue in the Russian scientific literature.

The aim of our study is to identify risk factors for PJK in patients with idiopathic scoliosis operated on using segmental instrumentation.

Material and Methods

Radiographs of 95 patients with idiopathic scoliosis operated on using segmental instrumentation were analyzed. The duration of the follow-up period was two years.

Selection criteria: idiopathic scoliosis, high-quality radiographs that allows reliable assessment of the value and extent of kyphosis in the upper thoracic spine, follow-up period of at least two years after the surgery. The patients' population included 82 women and 13 men. The age of the patients at the time of the surgery ranged from 8 to 43 years (mean age 17.8 ± 7.15 years). The value of thoracic kyphosis exceeded 40° (mean value of 58.03° ± 13.51°) in 34 patients, ranged between 20° and 40° (mean value of 30.83° ± 5.13°) in 30 patients and was less than 20° (mean value of 11.6° ± 4.61°) in 34 patients.

Analysis of X-ray images included assessment of thoracic kyphosis and lumbar lordosis parameters according to Cobb, assessment of scoliotic arc and sagittal balance, defined as a distance between a lead line from the C7 vertebra centroid and craniodorsal edge of the S1 vertebra (assessed as positive for ventral displacement and as negative for dorsal one). PJK was defined as 10° or more increase in the angle of kyphosis between the caudal endplate of the upper instrumented vertebra and the cephalad endplate of two adjacent proximal vertebrae as compared with preoperative angle at the same level. X-ray examination was performed before the surgery, within the first two weeks

after the surgery and at the end of the follow-up period (Fig.).

Spinal deformity was corrected using segmental posterior spinal instrumentation under skeletal traction conditions (skull and ankles). In addition, 32 patients underwent mobilizing discectomy and ventral fusion. Hybrid construction with additional pedicle fixation was used in 32 patients; in the remaining 63 patients the construction was fixed with hooks alone. Adaptation to the vertical position started three days after the surgery. On day 10–12 the patients were discharged home without external immobilization.

Based on the literature data [1–11], the following potential risk factors were selected for the analysis: initial value of the proximal transition angle, initial value of the thoracic kyphosis, transthoracic intervention, extent of the posterior spine fusion, changes in thoracic kyphosis parameters after the surgery, sagittal balance, the level of the upper instrumented vertebra, hybrid and laminar constructions, age at the time of the surgery, Risser test, gender of a patient. The statistical data processing was performed in Microsoft Office Excel 2007 using standard t-test.

Results

By the end of the 2-year follow-up PJK was observed in 23 (24 %) out of 96 patients. Prior to the surgery, the average value of the proximal transition angle was 6.7° ± 5.4° in patients with PJK (Group I) and 6.1° ± 4.6° in patients who have not developed PJK (Group II; P = 0.678). Within two weeks after the surgery, the angle in Group I more than doubled, while the changes in Group II were insignificant. Two years after the surgery further significant increase in junctional kyphosis angle was observed in Group I (Table 1).

Groups I and II differed noticeably in the preoperative thoracic kyphosis angle. In the early postoperative period, the kyphosis angle decreased by 14.9° in Group I and by 10.0° in Group II. By the end of 2-year follow-up the thoracic kyphosis decreased by 11.74° in Group I and by 8.89° in Group II, compared to the preoperative period.

The average length of the posterior spine fusion and Risser test were virtually identical in both groups. Age differences were not significant either. The observed differences between groups in values of the sagittal balance, in both preoperative and postoperative periods, were not significant according to the t-test.

The most pronounced correlation was observed between the postoperative PJK and preoperative proximal transition angle as well as transition angle two years after the surgery (Table 2). Patients with preoperative proximal transition angle between 0 to 5° developed PJK in 22.5% of cases (11 out of 49 patients), those with the transition angle of 6 to 12°, in up to 26 % (9 out of 34 patients), while those with the angle of 12° or more, in 27.3 % of cases. The correlation with preoperative and postoperative kyphosis was weaker. The difference between the initial angle of the thoracic kyphosis and the postoperative kyphosis demonstrated moderate positive correlation with the difference in the initial proximal transition angle and postoperative junctional kyphosis (r = 0.399; P = 0.048), as well as lack of correlation with PJK two years after the surgery (r = 0.093; P = 0.700). Weak or no correlation was observed for age at the time of the surgery, length of the posterior spine fusion, and Risser test.

By the end of the second year of follow up the prevalence of PJK in patients with hyperkyphosis was 38.2 %. In patients with normal kyphosis PJK developed in 20.0 % of cases, while in patients with lordoskoliosis, in 12.9 %.

PJK developed in 29.3 % of patients with postoperative decrease in the thoracic kyphosis of 5° or more (17 out of 58 cases), 14.8 % of patients with a change in the thoracic kyphosis of 5° degree or less in either direction (4 out of 27 cases), and 20.0 % of patients with increase in the thoracic kyphosis of 5° or more (2 cases out of 10, P < 0.0001). 25.0 % of patients who underwent ventral spinal fusion developed PJK compared to 20.0 % of the patients who did not undergo ventral intervention. 23.0 % of men and 24% of women developed PJK. Patients who had laminar fixation installed had PJK incidence of 17.5 % compared to 37.5 % in patients with hybrid fixation. PJK developed in 21.5 % of patients with fusion length of 10–12 vertebrae, and in 25.3 % of patients with the fusion length of 12 vertebrae or more.

Fig.
Radiographs of the patient K., female, 15-year-old, with idiopathic scoliosis; the development of the proximal junctional kyphosis in the postoperative period:
a – initial value of the junctional kyphosis between the expected level of the upper instrumented vertebra and two proximal vertebrae; **b** – two weeks after surgery the proximal junctional kyphosis increased to 17°; **c** – 2 years after the surgery the proximal junctional kyphosis increased to 25°

PJK developed in 20.0 % of patients with the topmost instrumented vertebrae located at Th3 level, 24.0 % of Th4 level cases, and 37.5 % of Th5 level cases (Table 3).

Discussion

The incidence of PJK by the end of the two-year follow-up period in patients with idiopathic scoliosis operated on using dorsal instruments amounted to 24 %. The study has shown that the use of hybrid metal construction (proximal hooks and distal transpedicular fixation) is associated with higher incidence of PJK compared to the use of laminar fixation alone. The reasons more frequent development of PJK in patients with a hybrid construction have not been identified in the present study. Patients with initial hyperkyphosis of the thoracic spine had higher incidence of PJK by the end of the second year of the follow-up compared to patients with normal kyphosis and lordoscoliosis. It implies that patients with thoracic kyphosis of more than 40° have a tendency to develop PJK in the postoperative period. Higher incidence of PJK was also observed in patients with early postoperative decrease in the thoracic kyphosis of 5° and more compared with patients whose thoracic kyphosis increased by 5° or more as well as those with changes in kyphosis in either direction within 5°.

A moderate correlation was observed between postoperative kyphosis of the thoracic spine and postoperative junctional kyphosis. The difference between the initial and postoperative thoracic kyphosis angle was positively correlated with the difference between the initial proximal transition angle and postoperative junctional kyphosis. These data suggest that a significant change in the thoracic kyphosis can lead to PJK. The initial value of the proximal transition angle showed moderate correlation with PJK after the surgery, as well as positive correlation with PJK two years after the surgery. Patients with the initial value of the proximal transition angle from 0 to 5° were the least likely to develop PJK, while the increase in preoperative values of the proximal transition angle was associated with significant increase in the incidence of postoperative PJK. It suggests that the higher the initial value of the proximal transition angle is the greater is the risk of PJK. The more distal location of the upper instrumented vertebra can also be a factor in the development of PJK, as the data show that the involvement of Th_5 resulted in PJK in 37.5 % of cases, whereas the involvement of Th_3 level resulted in PJK only in 24.0 % of cases. The possible causes of this effect will be discussed in subsequent papers.

A 5 % increase in PJK incidence in patients who underwent ventral spinal fusion compared to patients without ventral intervention can be attributed to the fact that in the majority of cases this type of intervention was employed in patients with rougher and more rigid deformities rather than with the execution of the ventral intervention itself. The study found that length of the posterior spinal fusion and the

Table 1

Comparative characteristics of the study groups

Parameter	Group I (n = 23)	Group II (n = 72)	P
Age at the time of the surgery, years	18,9 ± 9,2	17,2 ± 6,4	0,399
Extent of the fusion, number of segments	12,9 ± 0,8	13,0 ± 0,7	0,611
Risser test	3,1 ± 1,7	3,0 ± 1,7	0,781
Thoracic kyphosis according to Cobb, degrees			
preoperatively	45,9 ± 21,9	30,9 ± 20,0	0,006
after the surgery	31,0 ± 10,7	20,9 ± 10.2	0,0003
2 years after surgery	34,1 ± 14,4	22,0 ± 12,5	0,001
Sagittal balance, mm			
preoperatively	16,2 ± 13,9	19,4 ± 13,7	0,379
after the surgery	19,6 ± 15,5	24,6 ± 17,5	0,199
2 years after surgery	27,5 ± 19,2	34,1 ± 20,3	0,166
Proximal transition angle degrees			
preoperatively	6,7 ± 5,4	6,1 ± 4,6	0,678
after the surgery	15,0 ± 6,7	6,9 ± 4,4	<0,0001
2 years after surgery	23,0 ± 6,0	8,4 ± 5,6	0,001

Mean and standard deviation, a statistically significant difference (P < 0.05)

Table 2

Pearson's correlation coefficients between the postoperative proximal junctional kyphosis and different parameters

Parameter	Correlation coefficient (R) and significance (P)
Preoperative proximal transition angle	R = 0,567 (P < 0,0001)
Proximal transition angle two years after the surgery	R = 0,471 (P = 0,0002)
Preoperative kyphosis	R = 0,285 (P < 0,0001)
Age at the time of the surgery	R = 0,321 (P < 0,0001)
Postoperative kyphosis	R = 0,038 (P = 0,240)
Risser test	R = 0,047 (P < 0,0001)
Extent of the fusion	R = -0,152 (P = 0,152)

R = «-» negative correlation; R0 = no correlation; R = 0.1-0.3, weak positive correlation; R = 0.3–0.7, moderate positive correlation.

Table 3
Distribution of patients based on risk factors

Risk factor	Patients (n = 95)	Patients with proximal junction kyphosis (n = 23)	P
Preoperative thoracic kyphosis			
greater than 40°	34	13	<0,0001
20–40°	30	6	
Less than 20°	27	4	
Ventral spine fusion			
Yes	32	8	0,0001
No	60	12	
Gender			
Male	30	3	0,007
Female	82	20	
Instrumentation			
Laminar	63	11	0,005
Hybrid	32	12	
Length of the spinal fusion			
10–12 vertebrae	28	6	0,17
More than 12 vertebrae	67	17	
The topmost instrumented vertebra			
Th_3	20	5	0,72
Th_4	50	12	
Th_5	16	6	

initial sagittal balance do not affect the development of PJK. The incidence of PJK among men and women was almost identical (23 and 24 %, respectively). PJK was not clinically significant in any of the clinical cases studied and did not require the second surgery.

Conclusion

Initial hyperkyphosis, significant decrease in its value after the surgery, initial value of the proximal transition angle, distal location of the upper instrumented vertebra, and the use of hybrid fixation are significantly correlated with the development of PJK in the postoperative period. Transthoracic intervention, length of the posterior spine fusion, patient's age and gender, and Risser test had no correlation with the development of PJK.

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Address correspondence to:
Sergunin Aleksandr Yuryevich
NIITO, Frunze str., 17, Novosibirsk, 630091, Russia, saport@ngs.ru

Aleksandr Yuryevich Sergunin, junior researcher; Mikhail Vitalyevich Mikhailovsky, MD, DMSc, Prof.; Artyom Nikolayevich Sorokin, MD, PhD, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Russia.