SELECTION OF THE OPTIMAL DISTAL FUSION LEVEL FOR CORRECTION OF SCHEUERMANN'S HYPERKYPHOSIS*

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Objective. To analyze the efficacy of the method for selecting the distal level of fusion in treatment of thoracic hyperkyphosis in patients with Scheuermann's disease.
Material and Methods. Over the period of 2007—2010 years 36 patients were operated in the Department of Children and Adolescent Spine Pathology. Patients were divided into two groups: in Group I (n = 29) a lower instrumented vertebra (LIV) corresponded to the sagittal stable one and in Group II (n = 7) this vertebra located proximally.
Results. The mean preoperative magnitude of kyphosis was 79.3° ± 11.6°, postoperative — 40.6° ± 11.9° (correction 49.9 %), loss of correction was 4.9° ± 7.0°. Sagittal balance changed from -0.3 ± 3.2 cm before surgery to -1.7 ± 2.1 cm. Distal junctional kyphosis (DJK) developed in 1 case (4 %) in Group I, and in 5 cases (71 %) in Group II.
Conclusion. Distal level of instrumentation ending at the first lordotic vertebra is not justified and causes violation of sagittal balance and development of distal junctional kyphosis. The inclusion of a sagittal stable vertebra in fusion prevents the development of distal junctional kyphosis.
Key Words: Scheuermann's kyphosis, level of fixation, sagittal stable vertebra, distal junctional kyphosis (DJK).

**Mikhailovsky MV, Sorokin AN, Novikov VV, Vasyura AS. [Selection of the Optimal Distal Fusion Level for Correction of Scheuermann's Hyperkyphosis]. Hirurgia pozvonocnika. 2012;(2):24—29. In Russian. DOI: https://doi.org/10.14531/ss2012.2.24-29*

Scheuermann's disease is the most frequent cause of hyperkyphosis development in adolescent patients. However, only a few publications by Russian authors have been devoted to surgical treatment of this pathology using modern segmental instrumentation. These are articles by R.E. Raye [5], M.V. Mikhailovsky, et al. [2–4] and S.T. Vetrile et al. [1]

Selection of the optimal fusion level is an important stage in preoperative planning of thoracic hyperkyphosis correction. The fusion area needs to include all the kyphotic deformity [18, 19]. Many surgeons are consistent with the opinion that the upper border of the fusion must lie at the level of proximal vertebra in the kyphosis being measured [10, 15, 17]; however, precise levels of the distal fixation have not been determined yet. Construction should not end at the caudal vertebra within deformity in order to prevent the development of the distal junctional kyphosis. DJK has a significant clinical value, since it may cause pain syndrome and can also result in inconsistency of the instrumental caudal claw. Its development is unfavorable anyway. Ascani, La Rosa [6] recommended to extend the metal construction for one level lower than the origin of the transitional level and to fix the L1 vertebra. Wenger, Frick [20] supposed that posterior fusion needs to be performed at the T3–T12 levels. It is believed nowadays that the instrumental fixation area should include the vertebra localized distally with respect to the first lordotic disc [10, 15, 16]. However, the development of the DJK was observed even when these rules were maintained (Fig. 1).

Incorrect selection of the optimal fusion distal level may result in the development of DJK [7, 17]. It is difficult to determine the distal level of kyphosis, since vertebral bodies are cuneiform and (arch) lamina are rough in patients with Scheuermann's disease. It is often impossible to precisely measure the changes in the cuneiformity of discs in the thoracolumbar spine [15]. The method described by Cho, Lenke [8] was used in this study. During the course of formation of the distal claw, they selected the SSV that is the most proximal vertebra through which the posterior sacral vertical line (PSVL) goes (a line going vertically from the upper posterior sacrum as seen in the lateral X-ray film). This vertebra must be fixed (Fig. 2).

The objective of this study was to analyze the efficacy of the Cho–Lenke method for selecting the distal level of fusion in the treatment of Scheuermann's hyperkyphosis (in patients with Scheuermann's disease). Special attention was paid to the association between the SSV, the first lordotic vertebra (localized caudally from the first lordotic disc below the kyphotic deformity), the LIV, and the formation of the DJK in the postoperative period.

Material and Methods

Retrospective analysis of treatment outcomes was performed in 36 patients (32 males, 4 females) with kyphotic deformities of spine caused by Scheuermann's disease. The patients were surgically treated in 2007–2010 at the Department of Children and Adolescent Spine Pathology. Mean age of patients was 19.0 ± 3.0 (14–32) years. The

Fig. 1
X-ray films of 14-year-old patient L.: posterior fusion at the T4–L2 level, sagittal stable vertebra (SSV) – L3; development of distal transient kyphosis at the L2–L3 level 2 years after surgery

Fig. 2
Determination of the sagittal stable vertebra (SSV): the posterior sacral vertical line (PSLV)

patients were divided into two groups: in group I (n = 29), the LIV was the SSV and in group II (n = 7), it was proximal to the SSV. The follow-up period was 2.0 ± 1.3 years.

Radiographic examination was performed before and after surgery and during the follow-up period of 2 years. Kyphosis was measured according to Cobb [9]. Sagittal balance was estimated in lateral X-ray films of patients in the standing position. The ratio between the plumb line extending from the centroid of the C7 vertebra to the upper posterior angle of S1 was measured. If the plumb line went behind the sacrum, the sagittal balance was considered to be negative. In order to estimate the position of the distal end of instrumentation with respect to the sacrum, the distance between the centroid of the lower instrumented vertebra and the posterior sacral line was measured. The negative balance implied that the lower instrumented vertebra was located posterior to the sacrum. Distal transient kyphosis was measured by a kyphotic change in the disc localized caudally from the lower instrumented vertebra. The kyphotic deformity apex localized at the T7 (n = 11), T8 (n = 18), T9 (n = 5), and T10 (n = 2) levels. Only 5 patients were operated on using dorsal fixation (14 %), while 31 patients (86 %) were operated on using ventral fusion combined with posterior fixation with segmental instrumentation. In order to form the caudal claw, transpedicular screws and laminar hooks were used in 10 and 26 cases, respectively. The variability in lengths of dorsal and ventral fusions is summarized in Table 1.

Statistical analysis was performed using SPSS software (version 15.0); the non-parametric Mann–Whitney and Kruskal–Wallis tests were used to assess the intergroup difference. The threshold level of statistical significance was lower than 0.01 ($P < 0.01$).

Results

The mean angle of kyphotic deformity in patients in the standing position was 79.3° ± 11.6°. The deformity reduced to 40.6° ± 11.9° after surgical correction (49.9 %, Table 2).

Sagittal balance in group I changed from -0.3 ± 3.2 cm before surgery to -1.7 ± 2.1 cm at final follow-up. In group II, the changes were from -0.4 ± 2.5 to -1.9 ± 2.2 cm (Table 2).

Therefore, the negative sagittal balance increased after surgery in both groups.

In group I, the center of the lower instrumented vertebra was placed behind the sacrum before surgery; the distance between it and the posterior sacral line was -0.9 ± 1.67 cm. The balance was normalized after surgery: the center of the lower instrumented vertebra localized above the sacrum (0.11 ± 1.89 cm), this location persisted over the follow-up period (-0.28 ± 1.06 cm). In group II, the lower instrumented vertebra localized behind the sacrum (-3.37 ± 0.71 cm); however, this localization remained virtually unchanged by the end of the follow-up period (-2.53 ± 1.16 cm). The intergroup difference in the distance between the lower instrumented vertebra and the posterior sacral line was statistically significant (P < 0.01). The most likely reason for this is that the lower instrumented vertebra in group II was one level higher than that in group I.

Complications. DJK developed in 6 cases; caudal claw was performed with laminar hooks in all these cases. No DJK was found when transpedicular fixation was used. Only 1 case was detected in group I. The inconsistency of the lower points of anchorage was detected in this case, which made it necessary to repeat the distal capture of an endocorrector. In group II, DJK was found in 5 patients. The inconsistency of caudal capture was detected in 2 cases, requiring remounting of the instrumentation, changing hooks for transpedicular fixation, and extension of the fusion area (Fig. 3).

Other complications were associated with the development of proximal junctional kyphosis (n = 6), which was

Table 1

Fusion levels and the sagittal stable vertebra (SSV)

Kyphosis	Anterior fusion	Posterior fusion	First lordotic disc	SSV
Group I				
T4–T12	T6–T10	T3–L3	T12–L1	L2
T4–L1	T7–T10	T3–L3	L1–L2	L3
T4–T12	not performed	T4–L2	T12–L1	L2
T4–T12	T8–T12	T4–L3	T12–L1	L2
T4–T12	T7–T11	T3–L1	T12–L1	L1
T4–L1	T9–T12	T4–L3	L1–L2	L3
T3–T12	T7–T10	T4–L3	T12–L1	L2
T3–T12	T6–T9	T3–L3	T12–L1	L2
T3–T12	T6–T10	T3–L3	T12–L1	L2
T3–L2	T8–T11	T3–L4	L2–L3	L3
T4–T12	T7–T10	T4–L3	T12–L1	L2
T6–L2	T10–L1	T5–L4	L2–L3	L4
T4–L1	not performed	T4–L3	L1–L2	L2
T3–T12	T7–T10	T4–L3	T12–L1	L2
T4–T12	T6–T9	T3–L3	T12–L1	L3
T6–L2	T10–T12	T5–L4	L2–L3	L3
T3–T12	T6–T10	T3–L2	T12–L1	L2
T4–T12	T6–T9	T4–L3	L1–L2	L2
T4–L1	T8–T11	T4–L3	L1–L2	L2
T3–T12	T7–T10	T3–L4	T12–L1	L2
T3–T12	T7–T10	T4–L3	T12–L1	L2
T4–T12	T7–T10	T4–L2	T12–L1	L1
T4–L1	T8–T12	T4–L2	L1–L2	L2
T3–T12	T6–T8	T3–L2	T12–L1	L2
T3–T12	T6–T8	T3–L3	T12–L1	L2
T5–T12	T9–T12	T5–L3	T12–L1	L3
T3–L2	T9–T12	T4–L3	L2–L3	L3
T3–T12	not performed	T4–L2	T12–L1	L2
T3–L1	T7–T9	T3–L3	L1–L2	L3
Group II				
T3–T12	T8–T12	T4–L2	T12–L1	L3
T3–T12	T7–T10	T4–L2	T12–L1	L2
T3–T12	T4–L1	T7–T9	T12–L1	L2
T3–T12	T6–T9	T3–L2	T12–L1	L3
T4–T12	T8–T12	T4–L2	T12–L1	L3
T3–L1	not performed	T3–L1	L1–L2	L3
T3–T12	not performed	T4–L2	T12–L1	L4

Table 2

Results of surgical correction of kyphotic deformity in patient groups (M ± m)

Parameters	Total (n = 36)	I (n = 29)	II (n = 7)	P < 0.01
Kyphotic deformity before surgery in the standing position, deg	79.3 ± 11.6	81.6 ± 10.9	70.0 ± 10.1	0.03
Kyphotic deformity in the hyperextended position, deg	53.7 ± 11.4	55.6 ± 11.7	46.0 ± 6.1	0.02
Kyphotic deformity after surgery, deg	40.6 ± 11.9	41.2 ± 12.5	38.5 ± 9.9	0.47
Correction, %	49.9	49.6	45.00	–
Kyphotic deformity by the end of the follow-up period, deg	45.5 ± 13.2	45.7 ± 13.2	44.4 ± 14.0	0.84
Correction loss, deg	4.9 ± 7.0	4.5 ± 7.0	5.9 ± 7.6	0.66

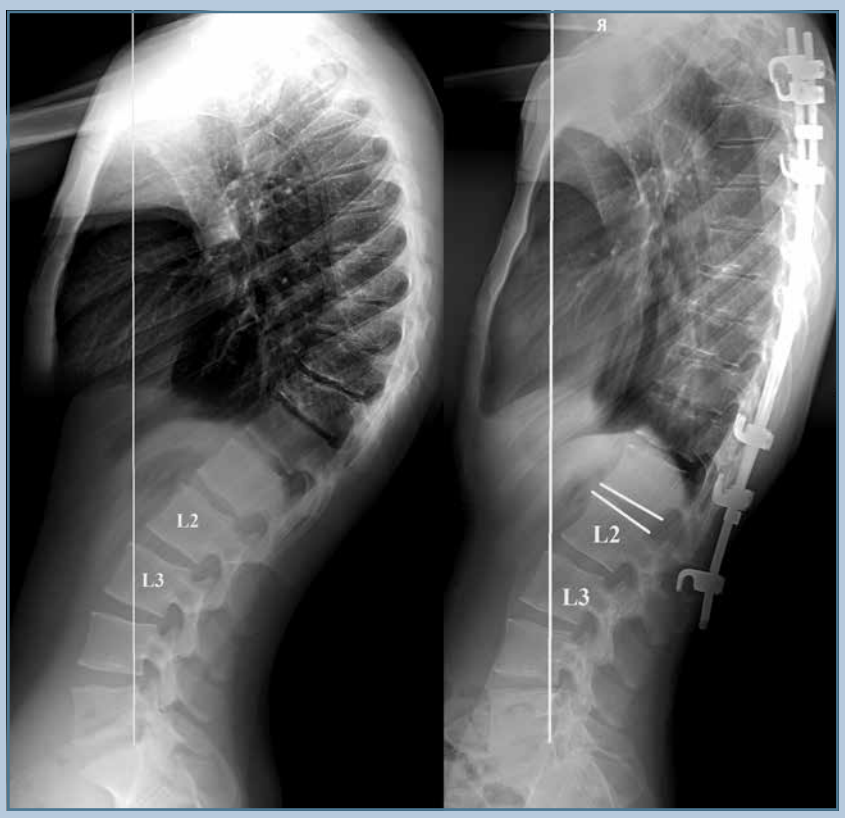

Fig. 3
X-ray films of 17-year-old patient Sh.: inconsistency of the instrumentational caudal claw caused by the development of DJK 1 year after surgery

asymptomatic and was detected in the control X-rays. In 2 cases, the inconsistency of instrumented cranial capture developed and required remounting of the endocorrector. Neither neurologic nor inflammatory complications were observed.

Discussion

The selection of a fusion level is the most important factor in treatment of hyperkyphosis. Inadequate choice may disturb the overall sagittal balance of the spine and cause kyphosis development below or above the metal construct. King et al. [14] suggested a theory of preoperative planning to be used in patients with idiopathic scoliosis. According to this theory, the caudal end of a construct is to reside at the stable vertebra, which facilitates normalization of the spine balance. The same principle can be applied to kyphotic deformities. Caudal claw of the instrumentation must include the SSV. If this rule is maintained, the LIV localizes above the sacrum, which allows normalization of the sagittal balance of the spine.

Global negative balance increased after surgery [12, 15]. Installation of the segmental instrumentation shifts the rotation axis in the middle column of the spine backward from the center-of-gravity in the sagittal plane [13]. In order to maintain the sagittal balance after surgery, both proximal and distal ends of the instrumentation must be as close as possible to the line of the center-of-gravity: the distal end of the instrumentation, at the SSV; the proximal end of the fusion should be the upper end of the measured kyphosis. In this study, there was a trend toward the stronger negative balance in the group II patients; however, the difference between the groups was insignificant ($P < 0.01$). The distance between the LIV and the PSVL was larger in group II. The lower instrumented vertebra localized behind the posterior sacral vertical line in this group. This disturbed the global sagittal balance, resulting in compensatory development of DJK. In group I, where the LIV coincided with the sagittal stable one, the lower end of the construct localized at the center of the sacrum, maintaining the balance of the spine.

Development of junctional kyphosis above or below the iron is a serious problem emerging after the surgical correction of the kyphotic deformity in patients with Scheuermann's disease. The DJK is of the most importance because it causes pain syndrome in the lumbar spine [11]. Proximal junctional kyphosis is often asymptomatic [7, 15]. Bradford et al. [7] described the loss of correction and the development of junctional kyphosis below the construct in 5 of 24 patients, while attributing it to the fact that the lower vertebra in the kyphosis being measured was not fixed. Lowe, Kasten [15] reported the development of DJK in 9 patients; the first lordotic disc was not fixed in 8 of these patients. In our study, the first lordotic disc was not fixed in one patient only, resulting in the development of junctional kyphosis below the metal construct. The caudal kyphotic vertebra was fixed in all cases. Nevertheless, despite the fact that all these rules were maintained, DJK developed in the postoperative period in 5 of 35 patients. In group I, the concept proposed by Cho, Lenke [8] was used to select the lower instrumented vertebra: the sagittal stable vertebra was determined, which allowed one to avoid development of DJK in 28 of 29 patients.

The use of screws as distal anchorage points reduced the risk of inconsistency in this part of instrumentation and in some cases allowed one to exclude one segment from the fusion.

Conclusion

The adequate choice of the fixation level when correcting hyperkyphosis prevents the development of junctional kyphosis above or below the construct. Finishing the mounting of a construct at the first lordotic vertebra rather than at the sagittal stable one is unjustified, since it often disturbs the sagittal balance and causes development of DJK. When using the SSV as the lower anchorage point, the caudal part of the endocorrector coincides with the center of the first sacral vertebra, thus maintaining the balance of the body. Hence, the inclusion of this vertebra in fusion is more likely to prevent the development of distal junctional kyphosis.

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Received February 1, 2012

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