GROWTH OF SPINAL MOTION SEGMENT IN CHILDREN AFTER VERTEBRAL BODY RESECTION IN THE THORACOLUMBAR AND LUMBAR SPINE*

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Objective. To assess the growth and development of the fused spinal motion segment in children operated on for congenital spinal deformity associated with disorders in vertebral formation using transpedicular fixation.
Material and Methods. The outcomes of surgery in 31 patients aged from 1 year and 9 months to 6 years and 11 months with a single congenital malformation of the spine were assessed. The surgery involved the hemivertebra resection, deformity correction with posterior instrumentation, corporodesis, and posterior local fusion of fixed spinal motion segments with autobone. The rate of bone block formation and the size of fused spinal motion segment in the region of hemivertebra resection were assessed on the basis of postoperative X-rays. New functional unit of the spine was compared to the adjacent intact vertebral bodies in dynamics.
Results. The mean follow-up period was 60 months. Solid bone fusion was achieved in all patients. The growth and development of the fused spinal motion segment in the region of hemivertebra resection kept pace with the growth of the adjacent intact vertebrae.
Conclusion. The fused spinal motion segment develops after hemivertebra resection without delay in increase in height and anterior-posterior dimension of fused vertebrae. After hemivertebra resection, the fused spinal motion segment is developing without delay in growth of height and anterior-posterior dimension of vertebral bodies involved in the block. New functional unit of the spine consistently develops and enables normal growth and development of the whole spine.
Key Words: fused spinal motion segment, congenital scoliosis, spine growth, transpedicular fixation.

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A few research papers devoted to the analysis of surgical treatment of children with congenital spine deformity caused by abnormal vertebrae development have been published [3, 4, 6, 8–11, 15]. A trend towards improving the methods for surgical treatment and variants of instrumental fixation is clearly seen in the historical aspect of solving the problems of congenital scoliosis and kyphoscoliosis. This is associated with the pursuit of attaining radical correction of congenital spine deformity and fixing the minimum number of spinal motion segments [3]. The complete correction of all deformity components, restoring the body balance, and providing facilities for the formation of physiological profiles of the spine, when the vertebral column and pelvic bones are being developed as interconnected structures of the locomotor system during the early age, contribute to correct and consistent development of a child in future.

In terms of biomechanics, the highest efficiency of deformity correction and stabilization of spinal motion segments involved in the pathological process is achieved when transpedicular screws are used as fixation elements of poste-

Table 1
Types of instrumental fixation

Fixation	Number of patients, n	Mean age of patients	Fixated spinal motion units, n	
			corporodesis	posterior fusion
Unilateral “hook + screw”	9	2 years and 9 months	1.0	2.5
Unilateral transpedicular	13	2 years and 7 months	1.0	2.0
Bilateral transpedicular	9	5 years and 6 months	1.0	1.9

rior metal instrumentation. Unlike hooks, screws enable one to affect all three vertebral columns and to rigidly fix the vertebrae [7, 12, 14].

This type of fixation and its effect on a spinal motion segment have been thoroughly studied in adults, in whom the bone skeleton has already completed. The question regarding the regularities of the development of an instrumented segment of the growing spine in patients of early age has not been totally elucidated yet. An experimental study of the transpedicular fixation procedure and its effect on a growing spinal motion segment made it possible to substantiate the use and to implement this type of stabilization for this patient category [1, 2, 5].

The available literature data devoted to the analysis of the features of the development of a fixed growing spinal segment after transpedicular fixation in children of early age are based on a very small number of observations and do not show any changes in the spinal motion segment in the dynamics [13].

We deem it necessary to unify the terminology used to assess the parameters of a growing spine and calculate the vertebral size after surgical intervention. Ruf and Harms [13] have denoted a structure consisting of two adjacent vertebrae near the hemivertebra resection area as the upper and lower instrumented vertebrae and calculated their parameters individually. In our opinion, it would be more correct to denote these vertebrae stabilized by metal instrumentation (with the defect being replaced by an autobone after hemivertebra resection) as a fixed spinal motion segment. After a bone block was formed between two vertebrae in the area of surgical intervention and the metal fixation device was removed, it would be more correct to denote this segment as the fused one, which indicates that it was formed as an integral bone structure with no mobility between its elements.

This study was aimed at assessing the growth and development of a fused spinal motion segment in children operated on for congenital scoliosis associated with vertebral malformation using transpedicular fixation.

Material and Methods

A total of 31 patients (12 boys and 19 girls aged from 1 year and 9 months to 6 years and 11 months) with single congenital malformation of the spine associated with vertebral malformation were followed up. The lateral and posterolateral hemivertebrae localized in the thoracolumbar passage (17 cases) and in the lumbar spine (14 cases). All children were subjected to surgical intervention through an anterolateral and posterior approach, which consisted in the resection of an abnormal vertebra with the adjacent discs, resection of the hemivertebral hemiarch, correction of the congenital deformity with posterior metal instrumentation, corporodesis, and posterior local fusion of the fixed spinal motion segments with an autobone.

Three tactical variants of instrumental fixation were used during the surgery (Table 1).

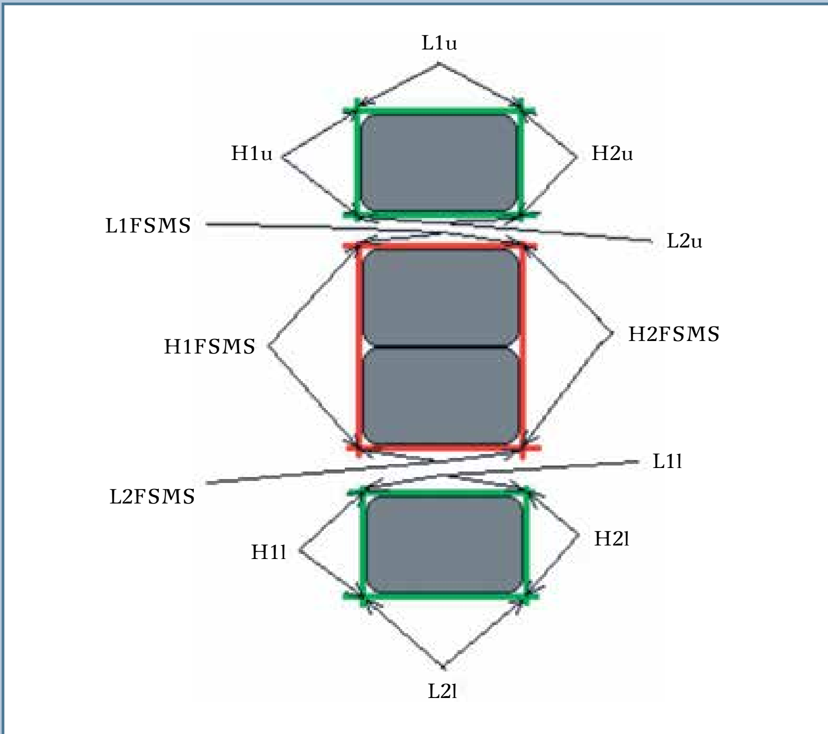

Fig. 1
Diagram for determining height and anteroposterior dimension of the bodies of the fused spinal motion segment (FSMS) and intact adjacent vertebrae using the lateral X-rays of the spine:
H1u – height of the anterior part of the body of the upper adjacent vertebra; H2u – height of the posterior part of the body of the upper adjacent vertebra; L1u – anteroposterior dimension of the upper part of the body of the upper adjacent vertebra; L2u – anteroposterior dimension of the lower part of the body of the upper adjacent vertebra; H1FSMS – height of the anterior part of the fused bodies; H2FSMS – height of the posterior part of the fused bodies; L1FSMS – anteroposterior dimension of the upper part of the fused bodies; L2FSMS – anteroposterior dimension of the lower part of the fused bodies; H1l – height of the anterior part of the body of the lower adjacent vertebra; H2l – height of the posterior part of the body of the lower adjacent vertebra; L1l – anteroposterior dimension of the upper part of the body of the lower adjacent vertebra; L2l – anteroposterior dimension of the lower part of the body of the lower adjacent vertebra

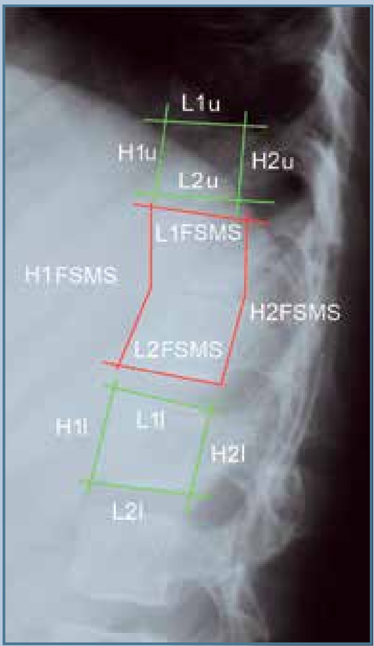

Fig. 2
Measuring the parameters of a fused spine motion segment (FSMS) and the adjacent vertebrae using the X-ray

After a solid bone fusion was formed in the area of surgical intervention (on average 1.5–2 years after surgery), the metal instrumentation was removed; the dynamic follow-up of the patients was continued. The follow-up period was 2–7 years (on average, 5 years and 3 months).

The parameters of the operated segments and the adjacent intact upper- and lower-lying vertebrae were assessed using the X-rays (front and lateral projections). The X-rays performed immediately after the surgical intervention and during the dynamic follow-up once per 12 months were analyzed. The anteroposterior X-ray images were used to assess the magnitude of scoliosis correction and the rate of bone fusion formation during child's growth. The lateral X-ray images were used to assess the magnitude of correction of the kyphotic deformity and to determine the height and the anteroposterior dimension of the fused segments formed by two vertebrae after hemivertebra resection and of the adjacent intact vertebrae (Fig. 1).

The procedure for assessing parameters of development of the fused spinal motion segment is based on the comparative analysis of the growth of these parameters in the dynamics of growth and development of the upper- and lower-lying intact vertebrae.

In order to ensure the accuracy of measurements and standardize them, the following provisions were taken into account:

– the size of the fused segment and the adjacent intact vertebral bodies were assessed using the lateral X-ray images, which allowed us to avoid distortions caused by physiological bowing of the spine in the sagittal plane, which cannot be eliminated using the anteroposterior X-ray alone;

– the height and anteroposterior dimension, which were determined by inscribing the contours of a vertebral body into a geometric figure represented by a rectangle (Fig. 1);

– the height and anteroposterior dimension of a fused spinal motion segment and the adjacent vertebral bodies were calculated by determining the arithmetic mean for each parameter: Hmean = H1 + H2 and Lmean = L1 + L2 (Fig. 2);

– the height and anteroposterior dimension of a fused segment were compared to those of the upper- and lower-lying vertebrae, thus accounting for the individual features of the growth and development rates typical of each patient.

The following parameters were analyzed when studying the anthropometric data based on the lateral X-ray of the spine: height and anteroposterior dimension of the fused spinal motion segment and the dynamics of growth of these parameters. The resulting indicators of growth of parameters during child's development were compared, enabling one to allow for the individual features of growth indicators for each patient.

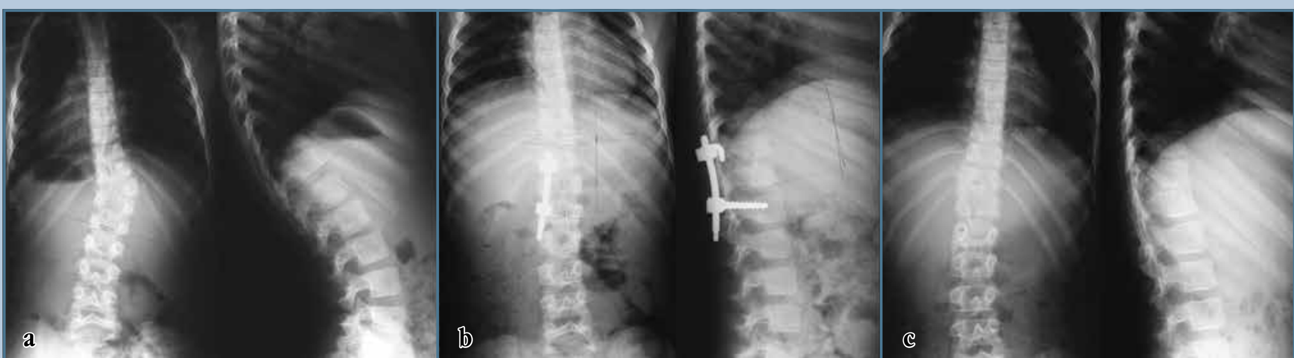

Fig. 3
X-ray images of patient N. (aged 2 years and 3 months) with congenital kyphoscoliosis associated with posterolateral T12 hemivertebra (D): **a** – before surgery; **b** – after surgery; **c** – 4 years after the metal instrumentation was removed

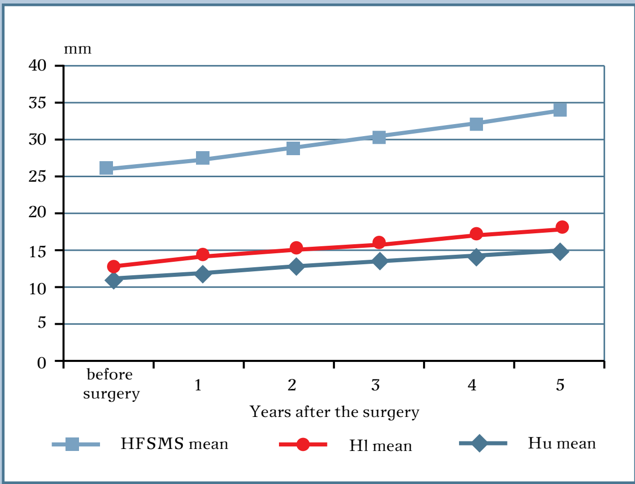

Fig. 4
Dynamics of the mean growth of the height of a fused spinal motion segment (FSMS) and the adjacent intact vertebral bodies

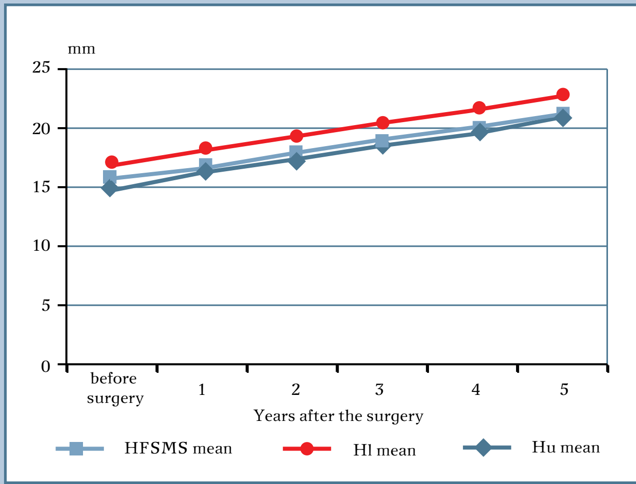

Fig. 5
Dynamics of the mean growth of the anteroposterior dimension (L) of a fused spinal motion segment (FSMS) and the adjacent intact vertebral bodies

Results and Discussion

The correction of scoliotic and kyphotic deformities after surgical intervention ranged from 85 to 100%. Neither neurological complications nor destabilization of metal instrumentation have been observed. The bone fusion in the surgery area was formed within 1.5–2 years; the spinal graft was removed after it. A solid bone fusion was formed in 100% of observations. The achieved correction of deformity was retained in all the patients during growth and development (Fig. 3).

The height and anteroposterior dimension of vertebral bodies of the fused spinal motion segment and the adjacent intact vertebrae showed a trend towards a uniform increase. The dynamics of the mean growth of the measured indicators is shown in Figs. 4 and 5.

Table 2 lists the indicators of relative growth of height and anteroposterior dimension of a fused spinal motion segment and the adjacent intact vertebral bodies immediately after the surgery and 5 years after the intervention.

The mean height the upper intact vertebral body after surgical treatment was 11.4 mm; after five years of follow-up observations it was 15.1 mm; the anteroposterior dimension was 15.2 mm, reaching 21.2 mm by the end of the follow-up period. The relative growth of the mean height and the anteroposterior dimension of the body of the adjacent upper vertebra was 24.8 and 28.1 %, respectively. The mean height of the bodies of a fused

Table 2
Growth of height (H) and anteroposterior dimension (L) of the fused spinal motion segment and the adjacent vertebral bodies

Indicators	After surgery, mm	5 years after the surgery, mm	Growth, %
Upper adjacent vertebra			
H1	11.2	15.2	26.4
H2	11.5	15.1	23.6
Hmean	11.4	15.1	24.8
L1	15.1	21.2	28.6
L2	15.3	21.2	27.7
Lmean	15.2	21.2	28.1
Fused spinal motion segment			
H1	25.6	33.7	23.9
H2	26.1	34.7	24.8
Hmean	25.9	34.2	24.4
L1	15.1	21.1	28.4
L2	16.5	21.9	24.7
Lmean	15.8	21.5	26.7
Lower adjacent vertebra			
H1	13.3	18.5	27.9
H2	13.2	17.8	25.8
Hmean	13.3	18.1	26.9
L1	16.8	22.9	26.6
L2	17.6	23.1	23.8
Lmean	17.2	23.0	25.2

spinal motion segment after surgery was 25.9 mm, reaching 34.2 mm after 5 years. The mean anteroposterior dimension of the bodies of the fused spinal motion segment during the follow-up period increased from 15.8 to 21.5 mm. The relative growth of the mean height and anteroposterior dimension of the bodies of the fused spinal motion segment was 22.4 and 26.7 %, respectively. The mean height and anteroposterior dimension of the body of the lower intact vertebra has increased from 13.2 and 17.2 mm to 17.8 and 23.0 mm, respectively, during the follow-up period (26.9 and 25.2 %).

Thus, the relative growth of the mean indicators of the bodies of the upper and lower adjacent vertebrae and the fused spinal motion segment has undergone the same changes. Over the entire follow-up period, the average growth of these indicators was 25.4 % (Hmean) and 25.7 % (Lmean) of the initial values.

The fused spinal motion segment is a new functional spinal unit that was formed between the bodies of the vertebrae adjacent to the hemivertebra resection zone. The newly formed structure develops in a consistent manner in accordance with the growth of the adjacent vertebral segments. The optimal conditions for its formation and further development include the radical correction of all the components of congenital deformity during surgical intervention and rigid instrumental fixation during the formation of a bone fusion as the child's organism is growing. The complete correction of the scoliotic and kyphotic components of the deformity enables ensuring proper formation of physiological bowing of the spine.

The use of instrumentation with transpedicular fixation elements in children (provided that a surgeon is proficient in using this type of fixation) is the optimal and efficient method that allows one to attain radical correction of the deformity and maintain the result during the follow-up period. Complete correction of the congenital scoliosis curve can be achieved by means of using transpedicular fixation elements at all three vertebral columns, while the result can be maintained due to the rigid and stable fixation.

Conclusions

Patients with congenital spine deformities associated with vertebral malformation should undergo radical correction of scoliosis. The dynamics of anthropometric indicators of a fused spinal motion segment after hemivertebra removal attests to the fact that it is developing without delay in growth of height and anterior-posterior dimension of vertebral bodies involved in the block. New functional unit of the spine consistently develops and enables normal growth and development of the whole spine.

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