# THE NATURAL COURSE OF CONGENITAL SPINAL DEFORMITY IN CHILDREN WITH ISOLATED VERTEBRAL BODY MALFORMATION IN THE LUMBAR SPINE

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**Objective.** To assess the natural history of the lumbar spine deformity progression in children with isolated vertebral body malformation. **Material and Methods.** The natural course of spinal deformity associated with disrupted lumbar vertebra formation was analyzed in 40 patients aged 1 year 7 months to 17 years 11 months who received conservative treatment and dynamic follow-up during four years. Spondylography was performed in frontal and lateral projections in lying position every 6 months. Spondylograms were used to measure the magnitude of the angle of the local scoliotic and kyphotic components of deformity in the process of child's growth and the magnitude of the angle of general lumbar lordosis. **Results.** The study showed that two components of deformity (scoliosis and kyphosis) were characterized by a progressive and stable course. Against the background of local curvature in the sagittal plane, the results of the study of general lordosis were distributed according to the age norm and to a flattening relative to the norm at the time of the last observation. **Conclusion.** At the primary examination of a patient, the initial magnitude of scoliotic curvature according to Cobb plays a predictive role in determining the further course of spinal deformity. When the magnitude of the primary curve is less than 30°, conservative therapy provides a stable course of congenital curvature, and in some children, a tendency to self-correction. Children with initial magnitude of the primary scoliotic curve of more than 30° have steady progression of congenital deformity in the lumbar spine of more than 6° during 4 years, which is an indication for surgical treatment at an early age. **Key Words:** lumbar spine, sacral spine, congenital scoliosis, hemivertebra, stable congenital deformity, progressive congenital deformity.

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Vertebral malformations that cause severe and rough deformity of the spine are localized in the zone of the thoracolumbar junction and in the lumbar spine in more than 50% of the observations [1]. Some authors refer to hemivertebrae of the lumbar and lumbosacral localization as the most severe congenital pathology of the vertebral column, since there is no possibility of compensation in the lower departments which leads to gross disruption of biomechanics in the spinopelvic system [8, 10].

The course of congenital deformity of the spine in children with vertebral malformations depends on initial magnitude of the primary curvature, the level of localization of the abnormal vertebra, and the type of a defect (scoliotic, kyphogenic, or kyphoscoliotic).

In Russian literature, there are only few studies assessing the course of congenital deformity of the spine in young children [2, 12]; according to them the negative impact of wedge-shaped vertebra and hemivertebra on the course of congenital curvature accrues with an increase of their number on the convex side of the deformity. Prognostic criteria for the development and progression of congenital deformity of the spine are based on the indicators of activity of malformed vertebrae, characterized by accessory growth plates in the area of bone lesion on the side of deformity, which are defined by the presence or absence of concrescence of anomalous vertebrae with the adjacent spinal motion segments [3, 4]. According to foreign researchers [6, 7, 9], 25 % of scoliotic deformities caused by hemivertebrae do not display any negative dynamics, 25 % progress slowly, and 50% display rapid progression of congenital curvature of the spine, which requires surgical treatment.

However, the authors do not single out the progression of isolated malformations, but instead present the data on vertebral malformation with and without malsegmentation.

The known indices predicting the rate of progression of congenital deformity, such as the index of hemivertebra activity (Ia) and the index of deformity progression (Ip), proposed by E.V. Ulrich,

as well as the coefficient of total dysplasia (Cd) proposed by S.A. Mikhailov have only historical value and are not used in practice. According to the data, probable signs of a potential rapid progression of scoliotic vertebral malformation include one-sided multiple hemivertebrae lying at the apex of the curve (100 %), initial magnitude of curvature of more than 50° (100 %), the progression index of more than 0.95 (80 %), pathological rotation of grade II and higher (80 %), alternating vertebrae separated from each other by more than 3 segments (75 %), initial magnitude of the curvature between 30 to 50° (70 %), and index of hemivertebra activity of more than 2.35 (70 %) [5]. However, according to observations, this probability of progression does not always correspond to reality, besides, calculation of some indices requires long-term dynamic evaluation of X-rays, which often leads to the formation of rough and rigid deformities of the spine in patients already in preschool age.

The objective of the study is to assess the natural course of the lumbar spine deformity progression in children with isolated vertebral body malformation.

## Material and Methods

The study includes data on 40 patients aged 1 year 7 months to 17 years 11 months with isolated vertebral malformation in the lumbar spine who received conservative treatment and dynamic follow-up over the course of four years. Conservative therapy included physical therapy aimed at strengthening the muscles of the back, shoulder girdle and abdominal muscles, stimulating back massage, physiotherapy, swimming and water procedures. Physical therapy (static and dynamic exercises) were prescribed to children older than three years of age and it was recommended to engage in it daily for at least 30-40 minutes a day in a form of a game. Back massage was carried out in courses of 15 sessions 2–3 times a year. Symmetrical swimming styles (breaststroke, butterfly) were recommended as water procedures for children older than five years.

Spondylography was performed in frontal and lateral projections from C7 to S2 vertebra in lying position. The spondylograms were used to assess the following parameters:

– magnitude of the angle of the local scoliotic and kyphotic components of deformity in the process of child's growth, measured according to Cobb, once every 6 months;

– magnitude of the angle of total lumbar lordosis;

– position of the pelvis in the frontal plane.

The total lordosis was assessed as the angle formed by the intersection of perpendiculars to the lines running along the cranial endplate of the L1 vertebra and the cranial endplate of the S1 vertebra. In case of abnormal L1 vertebra, the upper line was drawn along the cranial endplate of the lower thoracic vertebra. In case of hemivertebra localized in the region of the lumbosacral junction, the lower line was drawn along the cranial endplate of the sacral vertebra. The results were evaluated using the values proposed by Shefi et al. [11] (Fig. 1).

## Results

According to the results of the study and the dynamic follow-up, two components of deformity (scoliosis and kyphosis) were characterized by a progressive and stable course. Against the background of local curvature in the sagittal plane, the results of the spondilometric study of total lordosis were distributed according to the age norm and to a flattening relative to the norm at the time of the last examination.

In 14 (35 %) children, the scoliotic curvature progressed from 31 to 60° (Table 1).

During the follow-up period, the age of the children with progressing scoliotic component of deformity ranged from 2.7 to 17.1 years; 8 (57 %) hemivertebrae were localized in the region of the thoracolumbar junction, and 6 (43%) at the lumbar level. Progression of the scoliotic component of deformity was noted primarily in patients with posterolateral hemivertebra (86 %) compared with children with lateral hemivertebra (14 %). Supernumerary hemivertebrae (57 %) contributed to the progression of the scoliotic component in 57% of cases, whereas regular number of hemivertebrae in 43 % of cases. Segmented hemivertebrae led to the progression of the primary scoliotic curvature more often (86 %) than semi-segmented ones (14 %).

In 2009, the magnitude of the scoliotic curvature was 36° according to Cobb, in 2011 it was 45°, and in 2013 it was 55° (Fig. 2). Thus, over 4 years of follow-up the scoliotic curvature increased by almost 20°.

Stable scoliotic curvature was observed in 26 (65 %) patients. The age of children during the period of dynamic follow-up ranged from 3.7 to 13.9 years; 12 (46 %) hemivertebrae were localized at the thoracolumbar junction, 10 (38 %) at the lumbar level, and 4 (16 %) at the lumbosacral junction.

In case of stable scoliotic component of deformity, posterolateral hemivertebrae were observed in 16 (61 %) cases, and lateral ones in 10 (39 %). There was no progression of the scoliotic component in case of supernumerary hemivertebrae (92 %). Semi-segmented hemivertebrae were observed in 16 (62 %) cases of non-progression of scoliotic curvature, segmented hemivertebrae were observed in 8 (30 %) patients, unsegmented in 2 (8 %).

In 2011, the magnitude of the scoliotic component of deformity was 22° according to Cobb, in 2013 it was 21°, and in 2015 it was 20° (Fig. 3). Therefore, over 4 years of dynamic follow-up, there was no progression of the scoliotic component of the primary curvature.

Local pathological kyphosis progressed from 8 to 60° in 14 (35 %) children (Table 2).

The age of children with progression of local kyphosis during the follow-up period ranged from 4.1 to 17.1 years. Hemivertebrae were localized in the thoracolumbar (10,71 %) and in the lumbar spine (4,29 %). All 14 (100 %) hemivertebrae were posterolateral


| Age, yr | n | LA (meam ± SD) |
|---|---|---|
| 2–4 | 28 | 30 ± 6 |
| 5–7 | 41 | 34 ± 8 |
| 8–10 | 37 | 37 ± 7 |
| 11–13 | 27 | 39 ± 9 |
| 14–16 | 25 | 46 ± 7 |
| 17–20 | 52 | 44 ± 9 |

b

**Fig. 1**
The method for measuring the total lumbar lordosis **(a)** and lumbar lordosis norms in children from 2 to 20 years **(b)**, where age is the age group, n is the number of patients, LA is the lumbar lordosis according to Cobb with standard deviation

**Fig. 2**
X-rays of the spine of the patient L. (No 7) in the frontal projection, age from 6 years 4 months up to 10 years 2 months showing progressing scoliosis and posterolateral left-sided supernumerary semi-segmented L4 hemivertebra, concrescent with L3 vertebra

in terms of malformation variant. Supernumerary hemivertebrae led to progression of the kyphotic component of deformity in 57 % of cases (8 hemivertebrae), and in 43 % (6 hemivertebrae) of cases the anomalies were observed with regular number of hemivertebrae. Progression of the deformity in the sagittal plane was predominantly contributed by semi-segmented hemivertebrae in 10 (71 %) patients whereas by segmented ones in 4 (29 %).

In 2009, the local kyphosis magnitude was 12° according to Cobb, in 2011 it was 18°, and in 2013 it was 21° (Fig. 4). Therefore, over 4 years of follow-up the deformity increased by almost 9°.

Stable local pathological kyphosis was observed in 26 (65 %) children, whose age during the follow-up period ranged from 1.8 to 16.1 years. The distribution of hemivertebrae localization between departments of the spine was as follows: 10 (38 %) hemivertebrae were localized at the thoracolumbar junction, 12 (46 %) at the lumbar level, and 4 (16%) at the lumbosacral junction. The stable kyphotic component of deformity involved posterolateral hemivertebrae in 14 (54 %) cases, and the lateral ones in 12 (46 %). Stable kyphotic component was predominantly observed in case of the presence of supernumerary hemivertebra (92 %), regularly numbered hemivertebrae were involved in formation of stable kyphotic component in 2 (8 %) of cases. In the absence of kyphotic component progression the segmented vertebrae were observed in 16 (61.5 %) cases, semi-segmented in 8 (30.5 %) cases, and non-segmented in 2 (8.0 %).

In 2010, the local kyphosis magnitude was 2° according to Cobb, in 2012 it was 2°, and the same angle was observed in 2014 (Fig. 5). Therefore, over 4 years of growth and development of a child, the magnitude of the local kyphotic component at the level of the abnormal vertebra remained stable.

Joint progression of scoliotic and kyphotic components of deformity was observed in 6 (15 %) children; the joint stable course of the two components of

**Table 1**

The magnitude of local scoliotic component of deformity in patients with isolated vertebral malformation

| Patient | Age at the time of follow up, years | Magnitude of scoliosis, degrees | | | | | |
|---|---|---|---|---|---|---|---|
| | | at X-ray detection of hemivertebra | after 6 months | after 1 year | after 2 years | after 3 years | after 4 years |
| 1* | 13.5–17.4 | 53 | 54 | 55 | 57 | 59 | 60 |
| 2 | 5.1–9.3 | 14 | 14 | 14 | 14 | 14 | 14 |
| 3 | 9.3–13.4 | 22 | 22 | 21 | 21 | 20 | 20 |
| 4* | 1.7–5.7 | 33 | 33 | 34 | 36 | 38 | 40 |
| 5 | 4.7–8.5 | 26 | 22 | 23 | 23 | 22 | 23 |
| 6 | 6.6–10.7 | 15 | 14 | 14 | 14 | 14 | 14 |
| 7* | 6.4–10.2 | 36 | 42 | 44 | 45 | 46 | 55 |
| 8 | 4.1–8.2 | 25 | 26 | 26 | 26 | 26 | 26 |
| 9* | 13.7–17.1 | 54 | 58 | 54 | 55 | 57 | 59 |
| 10* | 3.8–7.6 | 33 | 35 | 35 | 36 | 37 | 40 |
| 11 | 3.1–7.7 | 27 | 22 | 22 | 22 | 22 | 22 |
| 12* | 10.6–14.8 | 42 | 53 | 53 | 54 | 54 | 55 |
| 13 | 9.0–13.2 | 24 | 25 | 25 | 24 | 23 | 23 |
| 14 | 5.1–9.1 | 21 | 19 | 16 | 15 | 16 | 15 |
| 15 | 9.9–13.5 | 28 | 28 | 28 | 28 | 28 | 28 |
| 16 | 4.4–8.7 | 16 | 17 | 17 | 17 | 18 | 17 |
| 17 | 6.5–10.2 | 26 | 21 | 21 | 21 | 22 | 22 |
| 18* | 12.1–16.8 | 44 | 51 | 50 | 50 | 51 | 52 |
| 19 | 7.8–11.6 | 27 | 27 | 28 | 28 | 28 | 28 |
| 20 | 8.3–12.3 | 23 | 23 | 23 | 21 | 23 | 24 |
| 21* | 3.6–7.8 | 33 | 33 | 36 | 37 | 39 | 38 |
| 22 | 6.2–10.5 | 17 | 17 | 20 | 21 | 20 | 20 |
| 23 | 4.2–8.1 | 24 | 25 | 26 | 26 | 27 | 27 |
| 24 | 5.1–9.1 | 19 | 21 | 21 | 20 | 20 | 22 |
| 25 | 7.3–11.3 | 21 | 22 | 24 | 24 | 24 | 25 |
| 26 | 6.7–10.6 | 13 | 13 | 13 | 14 | 15 | 15 |
| 27 | 5.3–9.1 | 11 | 12 | 12 | 12 | 13 | 14 |
| 28* | 10.8–14.6 | 46 | 50 | 52 | 52 | 55 | 56 |
| 29* | 13.1–17.7 | 43 | 49 | 54 | 56 | 55 | 56 |
| 30 | 9.4–13.3 | 29 | 28 | 28 | 29 | 29 | 29 |
| 31 | 3.7–7.1 | 25 | 25 | 23 | 24 | 26 | 26 |
| 32 | 7.6–11.8 | 24 | 24 | 24 | 25 | 26 | 26 |
| 33 | 9.2–13.0 | 22 | 23 | 24 | 23 | 23 | 24 |
| 34* | 13.4–17.5 | 48 | 50 | 53 | 55 | 57 | 59 |
| 35 | 4.7–8.4 | 27 | 28 | 28 | 28 | 27 | 28 |
| 36* | 6.2–10.4 | 35 | 37 | 40 | 43 | 44 | 46 |
| 37 | 9.5–13.9 | 24 | 24 | 23 | 24 | 25 | 26 |
| 38* | 12.8–16.1 | 48 | 48 | 51 | 52 | 55 | 56 |
| 39 | 4.5–8.7 | 25 | 26 | 26 | 26 | 25 | 24 |
| 40* | 2.7–6.7 | 33 | 37 | 37 | 35 | 36 | 39 |

*patients with progressing components of deformity.

deformity (scoliosis and kyphosis), in 18 (45 %) children.

Against the background of local curvature, the results of the spondylometric study of total lordosis were distributed according to the age norm and to a flattening relative to the norm at the time of the last examination. Flattening of the total lordosis according to age norms was observed in 20 (50 %) children and ranged from -30 to -14° (Table 3).

The characteristics of the hemivertebrae leading to the flattening

**Fig. 3**
X-rays of the spine of the patient Z. (No 3) in the frontal projection, age from 9 years 3 months up to 13 years 4 months showing stable scoliosis and posterolateral right-side supernumerary semi-segmented L4 hemivertebra, concrescent with L5 vertebra

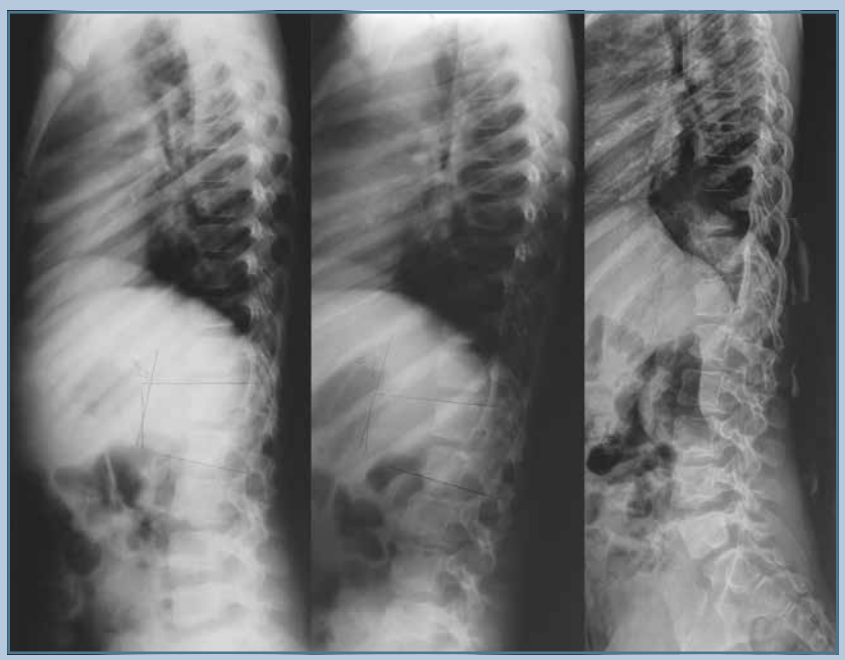

**Fig. 4**
X-ray of the spine of the patient M. (No. 20) in the lateral projection, age from 8 years 3 months up to 12 years 3 months showing progressive kyphosis and posterolateral right-sided supernumerary segmented L2 hemivertebra

of the total lordosis are presented in Table 4.

The magnitude of the total lumbar lordosis corresponded to the physiological age norm in 20 (50%) children (Table 5).

Statistical analysis showed that the values of the primary scoliotic curvature had log-normal distribution with the following density parameters: mean – 3.4, standard deviation – 0.28.

The values of the local pathological kyphosis at the time of X-ray detection of the deformity were distributed exponentially with the parameter $\theta$ = 0.06, the chi-square test was 0.38. The analysis of the natural course of scoliosis over 4 years revealed an association with the initial magnitude of the scoliotic curvature, which is well-illustrated by the scatter-plot of these two parameters (Fig. 6).

Figure 6 shows that the data for parameters under study visually diverge, basically forming two categories: category 1 in which the initial magnitude of the scoliotic curvature was up to and including 30°, and category 2 in which the initial magnitude of the scoliotic curvature exceeded 30°. On the histogram, the increase in the scoliotic component of deformity during the dynamic follow-up period of 4 years was distributed as follows: negative increase in 11 patients from category 1 (with a baseline scoliosis up to 30°), in three of them it was -7 to -9°, and in the others, -3 to -4°. Positive increase in scoliosis was observed in 15 patients from this category. All patients with initial local scoliosis of 31° and higher (14 patients) had positive increase in scoliosis. The exact Fisher test was used to assess statistical significance of differences in scoliosis dynamics over 4 years and the significance level P = 0.0036 was established. The Mann-Whitney criterion confirmed the difference between the two categories of patients in terms of increase in scoliosis angle values over 4 years at the significance level of P = 0.0002.

It was established that in case of increase in local kyphosis of less than 7° during the dynamic follow-up, the

magnitude of total lordosis approached the age norms. In addition, it was established that when the progression of the local kyphosis was higher than 7° during the growth and development of the child, the total lordosis remained below the age norm.

According to the results obtained, the children with the progression of local kyphosis of less than 7° over the period of the dynamic follow-up had larger increase in the angle of total lordosis compared to the patients with an increase in local kyphosis of more than 7°.

The Mann-Whitney criterion revealed statistically significant difference between the increase in local kyphosis and the increase in total lordosis at the significance level of $P = 0.027$.

The data obtained confirm that there were no children with a simultaneous progression of local kyphosis greater than 7° and the magnitude of total lordosis corresponding to their age norms in the study groups.

## Discussion

When the initial magnitude of the primary local scoliotic curvature in the lumbar spine was less than 30°, the conservative therapy was associated with stable course of deformity in 65 % of the children.

The stable course of congenital deformity during the dynamic follow-up manifested as preservation of the initial scoliosis angle in 5 % of patients, slight progression of the local primary curve, not exceeding 4° in 4 years, in 37.5 % of children, tendency towards self-correction of congenital curvature by 1–3°, in 22.5 %. All children with initial magnitude of local scoliotic curvature of more than 30° had steady progression of the congenital curvature in the range of 6–13° over 4 years of dynamic follow-up.

When the initial magnitude of the primary local kyphotic curvature in the lumbar spine was less than 7°, the conservative therapy was associated with stable course of deformity in the sagittal projection. The stable course manifested as the lack of deformity progression in 40 % of patients and minor increase in the magnitude of local kyphosis by 1–3° in 25 % of children. All children with initial magnitude of local kyphotic curvature in the lumbar spine of more than 7° had steady progression of the congenital curvature by 6–14° during the period of dynamic observation.

It was established that if, over the period of dynamic follow-up, the local angle of the kyphotic deformity in the lumbar spine was up to 7° inclusive, the magnitude of the total lordosis reached the age norm even in case of the initial flattening. In patients with progressive local kyphosis of more than 8°, the magnitude of total lordosis did not reach the age norm and kept flattening over the period of dynamic follow-up.

In our study, the localization of abnormal hemivertebrae did not affect the natural course of congenital deformity. In case of stable course of deformity and progression of the existing curvature, the most frequent localization of a malformed vertebrae was at the thoracolumbar junction. The lumbar localization of hemivertebrae occurred less often compared to the thoracolumbar localization in both progressing and stable congenital deformities of the spinal column. There were no cases of hemivertebrae located in the lumbosacral spine and leading to the progression of scoliotic deformity in our study. Pelvic tilt in the frontal plane was observed in all children with progressive course of congenital deformity of the lumbar spine. In case of progression of congenital deformity of the lumbar spine, the length of the scoliotic curvature increases via the involvement of vertebrae next to those adjacent to the abnormal one, and they start to develop pathological rotation.

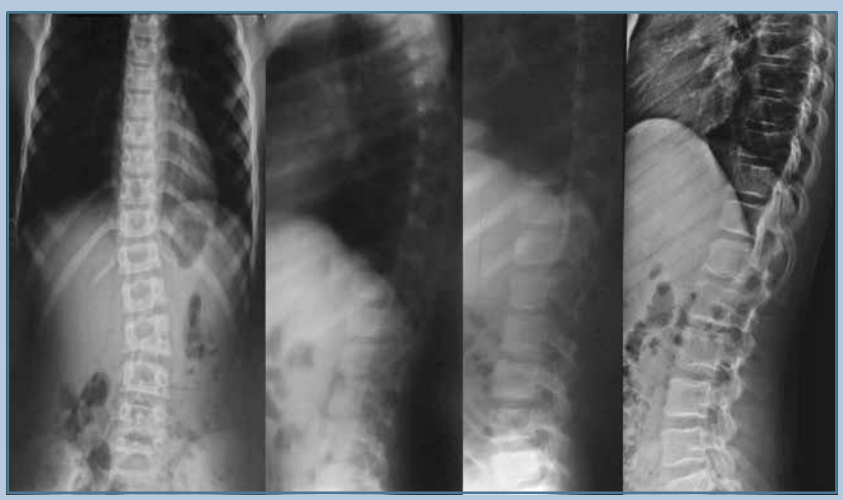

**Fig. 5**
X-rays of the spine of the patient C. (No 14) in the frontal and lateral projections, age from 5 years 10 months up to 9 years 11 months showing stable kyphosis and posterolateral left-sided supernumerary semi-segmented L3 hemivertebra, concrescent with L2 vertebra

## Conclusions

1. Posterolateral hemivertebrae lead to progression of all components of deformity more often than the lateral abnormal vertebrae for which no formation and progression of local pathological kyphosis at the level of the malformed vertebra was observed ($P < 0.05$).

**Table 2**

The magnitude of the local kyphotic component of deformity in patients with isolated vertebral malformation

| Patient | Age at the time of follow up. years | Magnitude of scoliosis, degrees | | | | | |
|---|---|---|---|---|---|---|---|
| | | at X-ray detection of hemivertebra | after 6 months | after 1 year | after 2 years | after 3 years | after 4 years |
| 1* | 13.5–17.4 | 60 | 60 | 60 | 60 | 60 | 60 |
| 2* | 5.1–9.3 | 8 | 9 | 11 | 13 | 14 | 15 |
| 3 | 9.3–13.4 | 4 | 1 | 2 | 1 | 2 | 4 |
| 4 | 1.7–5.7 | 2 | 4 | 3 | 4 | 5 | 4 |
| 5 | 4.7–8.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6* | 6.6–10.7 | 8 | 10 | 10 | 13 | 15 | 16 |
| 7 | 6.4–10.2 | 7 | 7 | 7 | 7 | 7 | 7 |
| 8* | 4.1–8.2 | 8 | 12 | 14 | 15 | 16 | 18 |
| 9* | 13.7–17.1 | 17 | 19 | 21 | 22 | 23 | 25 |
| 10 | 3.8–7.6 | 2 | 2 | 2 | 2 | 2 | 2 |
| 11 | 3.1–7.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12* | 10.6–14.8 | 10 | 18 | 20 | 22 | 23 | 24 |
| 13 | 9.0–13.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 5.1–9.1 | 5 | 6 | 4 | 6 | 5 | 6 |
| 15 | 9.9–13.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 4.4–8.7 | 11 | 11 | 10 | 10 | 11 | 11 |
| 17 | 6.5–10.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 12.1–16.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 7.8–11.6 | 6 | 6 | 7 | 7 | 7 | 7 |
| 20* | 8.3–12.3 | 12 | 14 | 18 | 18 | 20 | 21 |
| 21 | 3.6–7.8 | 3 | 3 | 3 | 2 | 3 | 3 |
| 22 | 6.2–10.5 | 0 | 0 | 0 | 0 | 1 | 1 |
| 23* | 4.2–8.1 | 8 | 9 | 12 | 14 | 15 | 17 |
| 24 | 5.1–9.1 | 2 | 2 | 4 | 6 | 5 | 5 |
| 25* | 7.3–11.3 | 13 | 13 | 15 | 17 | 19 | 19 |
| 26* | 6.7–10.6 | 8 | 11 | 16 | 19 | 18 | 19 |
| 27* | 5.3–9.1 | 9 | 9 | 10 | 12 | 13 | 15 |
| 28* | 10.8–14.6 | 12 | 12 | 16 | 17 | 21 | 23 |
| 29* | 13.1–17.7 | 16 | 19 | 22 | 23 | 23 | 24 |
| 30 | 9.4–13.3 | 0 | 0 | 0 | 1 | 0 | 0 |
| 31 | 3.7–7.1 | 0 | 0 | 2 | 3 | 3 | 3 |
| 32 | 7.6–11.8 | 6 | 7 | 7 | 7 | 6 | 6 |
| 33 | 9.2–13.0 | 0 | 1 | 1 | 3 | 3 | 3 |
| 34* | 13.4–17.5 | 56 | 56 | 57 | 58 | 60 | 60 |
| 35 | 4.7–8.4 | 2 | 1 | 1 | 2 | 2 | 2 |
| 36 | 6.2–10.4 | 3 | 3 | 4 | 5 | 5 | 6 |
| 37 | 9.5–13.9 | 0 | 1 | 1 | 1 | 2 | 2 |
| 38 | 12.8–16.1 | 4 | 6 | 6 | 5 | 6 | 6 |
| 39 | 4.5–8.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 2.7–6.7 | 4 | 4 | 3 | 3 | 4 | 4 |

*patients with progressing components of deformity.

2. The completeness of an malformed vertebra in the lumbar spine affects the natural course of congenital deformity. It was statistically established that the regular hemivertebrae basically do not occur in observations with stable course of congenital curvature, but lead to progressing course of congenital deformity ($P < 0.05$).

3. Segmented hemivertebrae lead to progression of the primary scoliotic

**Table 3**

The magnitude of total lordosis in patients with isolated vertebral malformations

| Patient | Age at the time of follow up. years | Total lordosis, degrees | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | age norm | at X-ray detection of the deformity | after 6 months | after 1 year | after 2 years | after 3 years | after 4 years |
| 1* | 13.5–17.4 | -44 ± 9 | -14 | -14 | -14 | -14 | -14 | -14 |
| 2 | 5.1–9.3 | -37 ± 7 | -30 | -30 | -31 | -33 | -33 | -35 |
| 3 | 9.3–13.4 | -39 ± 9 | -34 | -36 | -37 | -38 | -43 | -45 |
| 4 | 1.7–5.7 | -34 ± 8 | -40 | -40 | -41 | -41 | -42 | -42 |
| 5* | 4.7–8.5 | -37 ± 7 | -15 | -17 | -17 | -21 | -21 | -21 |
| 6 | 6.6–10.7 | -37 ± 7 | -31 | -31 | -33 | -33 | -35 | -35 |
| 7* | 6.4–10.2 | -37 ± 7 | -16 | -18 | -21 | -21 | -22 | -24 |
| 8* | 4.1–8.2 | -37 ± 7 | -26 | -26 | -28 | -28 | -27 | -27 |
| 9 | 13.7–17.1 | -44 ± 9 | -46 | -46 | -44 | -44 | -45 | -45 |
| 10* | 3.8–7.6 | -34 ± 8 | -22 | -22 | -23 | -23 | -24 | -24 |
| 11* | 3.1–7.7 | -34 ± 8 | -19 | -19 | -20 | -20 | -21 | -21 |
| 12* | 10.6–14.8 | -46 ± 7 | -28 | -28 | -29 | -29 | -30 | -30 |
| 13 | 9.0–13.2 | -39 ± 9 | -30 | -30 | -32 | -35 | -37 | -41 |
| 14* | 5.1–9.1 | -37 ± 7 | -15 | -15 | -18 | -20 | -20 | -24 |
| 15 | 9.9–13.5 | -39 ± 9 | -37 | -37 | -39 | -41 | -41 | -45 |
| 16* | 4.4–8.7 | -37 ± 7 | -22 | -24 | -24 | -26 | -28 | -29 |
| 17 | 6.5–10.2 | -37 ± 7 | -36 | -36 | -39 | -41 | -41 | -43 |
| 18* | 12.1–16.8 | -46 ± 7 | -16 | -20 | -24 | -25 | -26 | -28 |
| 19 | 7.8–11.6 | -39 ± 9 | -43 | -43 | -45 | -45 | -47 | -47 |
| 20* | 8.3–12.3 | -39 ± 9 | -14 | -18 | -20 | -24 | -24 | -26 |
| 21 | 3.6–7.8 | -39 ± 9 | -20 | -21 | -22 | -25 | -25 | -26 |
| 22 | 6.2–10.5 | -39 ± 9 | -34 | -36 | -37 | -40 | -39 | -40 |
| 23* | 4.2–8.1 | -44 ± 9 | -25 | -26 | -26 | -28 | -28 | -29 |
| 24 | 5.1–9.1 | -37 ± 7 | -17 | -18 | -20 | -21 | -23 | -25 |
| 25* | 7.3–11.3 | -37 ± 7 | -16 | -16 | -17 | -20 | -22 | -25 |
| 26 | 6.7–10.6 | -37 ± 7 | -30 | -31 | -32 | -34 | -34 | -36 |
| 27 | 5.3–9.1 | -37 ± 7 | -32 | -33 | -33 | -35 | -36 | -37 |
| 28* | 10.8–14.6 | -37 ± 7 | -25 | -27 | -28 | -28 | -29 | -30 |
| 29 | 13.1–17.7 | -44 ± 9 | -40 | -42 | -44 | -44 | -44 | -46 |
| 30 | 9.4–13.3 | -39 ± 9 | -37 | -37 | -38 | -40 | -44 | -47 |
| 31* | 3.7–7.1 | -34 ± 8 | -20 | -20 | -22 | -23 | -22 | -23 |
| 32* | 7.6–11.8 | -46 ± 7 | -41 | -41 | -42 | -44 | -45 | -47 |
| 33 | 9.2–13.0 | -39 ± 9 | -31 | -33 | -36 | -40 | -42 | -43 |
| 34* | 13.4–17.5 | -37 ± 7 | -16 | -16 | -17 | -17 | -17 | -18 |
| 35* | 4.7–8.4 | -34 ± 8 | -24 | -25 | -23 | -27 | -30 | -33 |
| 36* | 6.2–10.4 | -37 ± 7 | -16 | -17 | -18 | -20 | -24 | -25 |
| 37 | 9.5–13.9 | -37 ± 7 | -30 | -30 | -34 | -36 | -40 | -42 |
| 38* | 12.8–16.1 | -46 ± 7 | -16 | -17 | -18 | -20 | -22 | -25 |
| 39 | 4.5–8.7 | -39 ± 9 | -16 | -17 | -18 | -20 | -22 | -23 |
| 40 | 2.7–6.7 | -34 ± 8 | -42 | -45 | -45 | -48 | -48 | -47 |

*Patients with flattened total lordosis at the time of the last examination.

curvature in the lumbar spine more often than semi-segmented ones. However, in the course of dynamic follow-up, it has been established that semi-segmented hemivertebrae lead to the progression of local pathological kyphotic deformity in the lumbar spine, similar to segmented hemivertebrae.

4. At the initial examination of a patient, the initial magnitude of scoliotic curvature according to Cobb plays a predictive role in determining the further

**Table 4**

Characteristics of hemivertebrae associated with decrease in total lordosis

| Patient | Age at the time of follow up, years | Level of hemivertebrae | Variant of malformation | Localization | Completeness | Type of malformation |
|---|---|---|---|---|---|---|
| 1-й | 13.5–17.4 | 2 | Posterolateral | Dex | Regular | Segmented |
| 5-й | 4.7–8.5 | 7 | Lateral | Dex | Supernumerary | Segmented |
| 7-й | 6.4–10.2 | 3 | Posterolateral | Sin | Supernumerary | Segmented |
| 8-й | 4.1–8.2 | 3 | Posterolateral | Sin | Supernumerary | Semi-segmented |
| 10-й | 3.8–7.6 | 4 | Posterolateral | Sin | Supernumerary | Segmented |
| 11-й | 3.1–7.7 | 7 | Lateral | Dex | Supernumerary | Segmented |
| 12-й | 10.6–14.8 | 4 | Posterolateral | Dex | Supernumerary | Segmented |
| 14-й | 5.1–9.1 | 3 | Posterolateral | Dex | Supernumerary | Segmented |
| 16-й | 4.4–8.7 | 2 | Posterolateral | Dex | Supernumerary | Semi-segmented |
| 18-й | 12.1–16.8 | 2 | Lateral | Sin | Regular | Segmented |
| 20-й | 8.3–12.3 | 1 | Posterolateral | Sin | Supernumerary | Semi-segmented |
| 23-й | 4.2–8.1 | 2 | Posterolateral | Dex | Regular | Segmented |
| 25-й | 7.3–11.3 | 7 | Lateral | Dex | Supernumerary | Segmented |
| 28-й | 10.8–14.6 | 4 | Posterolateral | Dex | Supernumerary | Segmented |
| 31-й | 3.7–7.1 | 7 | Lateral | Dex | Supernumerary | Segmented |
| 32-й | 7.6–11.8 | 4 | Posterolateral | Dex | Supernumerary | Segmented |
| 34-й | 13.4–17.5 | 3 | Posterolateral | Dex | Supernumerary | Segmented |
| 35-й | 4.7–8.4 | 4 | Posterolateral | Sin | Supernumerary | Segmented |
| 36-й | 6.2–10.4 | 2 | Posterolateral | Dex | Supernumerary | Semi-segmented |
| 38-й | 12.8–16.1 | 2 | Lateral | Sin | Regular | Segmented |

Dex – right, Sin – left.

course of spinal deformity. When the magnitude of the primary curve is less than 30°, conservative therapy provides a stable course of congenital curvature, and in some children, a tendency to self-correction. Children with initial magnitude of the primary scoliotic curve of more than 30° have steady progression of congenital deformity in the lumbar spine of more than 6° during 4 years, which is an indication for surgical treatment at an early age (P = 0.0036).

5. When the initial value of the local kyphosis in the zone of the anomalous vertebra is less than 7°, a stable course of congenital deformity is reported during the dynamic follow-up period. In such children, the total lordosis in the lumbar spine over the four years of follow-up is approaching the age norms. When the initial value of the local kyphosis in the zone of the anomalous vertebra is 8° or higher, progression of congenital deformity is reported during the follow-up period (P = 0.027).

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**Table 5**

Characteristics of hemivertebrae associated with normal magnitude of total lordosis

| Patient | Age at the time of follow up. years | Level of hemivertebrae | Variant of malformation | Localization | Completeness | Type of malformation |
|---|---|---|---|---|---|---|
| 2 | 5.1–9.3 | 2 | Posterolateral | Sin | Regular | Semi-segmented |
| 3 | 9.3–13.4 | 4 | Posterolateral | Dex | Supernumerary | Non-segmented |
| 4 | 1.7–5.7 | 2 | Posterolateral | Dex | Supernumerary | Segmented |
| 6 | 6.6–10.7 | 2 | Posterolateral | Dex | Supernumerary | Semi-segmented |
| 9 | 13.7–17.1 | 3 | Posterolateral | Sin | Supernumerary | Non-segmented |
| 13 | 9.0–13.2 | 2 | Posterolateral | Dex | Regular | Semi-segmented |
| 15 | 9.9–13.5 | 1 | Lateral | Dex | Supernumerary | Semi-segmented |
| 17 | 6.5–10.2 | 6 | Lateral | Sin | Supernumerary | Semi-segmented |
| 19 | 7.8–11.6 | 5 | Lateral | Sin | Supernumerary | Segmented |
| 21 | 3.6–7.8 | 2 | Posterolateral | Sin | Supernumerary | Semi-segmented |
| 22 | 6.2–10.5 | 2 | Posterolateral | Sin | Supernumerary | Semi-segmented |
| 24 | 5.1–9.1 | 2 | Posterolateral | Sin | Regular | Semi-segmented |
| 26 | 6.7–10.6 | 2 | Posterolateral | Dex | Supernumerary | Semi-segmented |
| 27 | 5.3–9.1 | 3 | Posterolateral | Sin | Supernumerary | Non-segmented |
| 29 | 13.1–17.7 | 2 | Posterolateral | Dex | Regular | Semi-segmented |
| 30 | 9.4–13.3 | 6 | Lateral | Sin | Supernumerary | Semi-segmented |
| 33 | 9.2–13.0 | 1 | Lateral | Dex | Supernumerary | Semi-segmented |
| 37 | 9.5–13.9 | 5 | Lateral | Sin | Supernumerary | Segmented |
| 39 | 4.5–8.7 | 4 | Posterolateral | Dex | Supernumerary | Non-segmented |
| 40 | 2.7–6.7 | 2 | Posterolateral | Dex | Supernumerary | Segmented |

Dex – right, Sin – left.

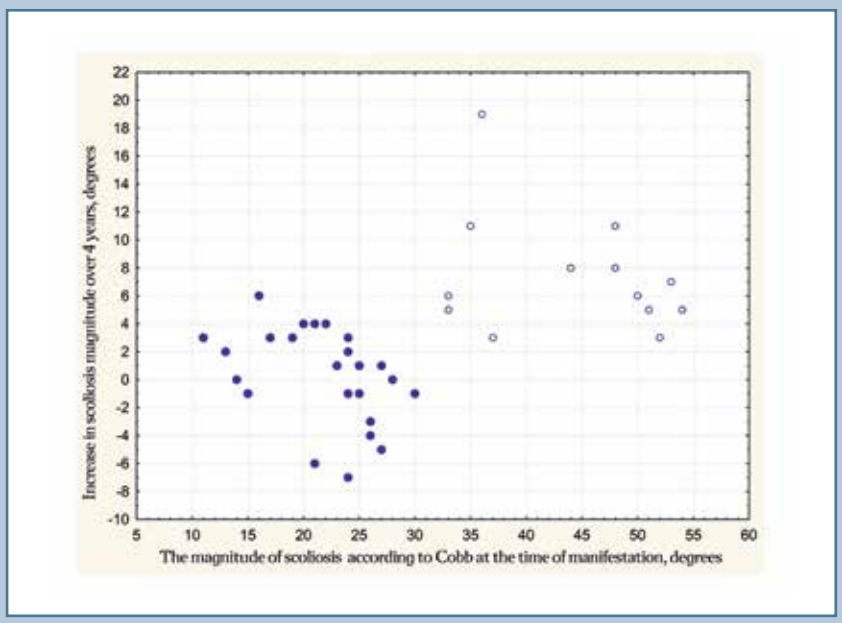


**Fig. 6**

Scattering diagram of the data for the manifestation of a scoliotic curvature and the dynamics of its course

## References

1. **Vissarionov SV.** Surgical treatment of segmental instability of the thoracic and lumbar spine in children. DMSc Thesis. St. Petersburg, 2008. In Russian.
2. **Vissarionov SV, Kazaryan IV, Belyanchikov SM.** Surgical treatment of preschool children with congenital developmental disorders in the lumbar spine. Hir. Pozvonoc. 2009;(4):44–49. In Russian. DOI: http://dx.doi.org/10.14531/ss2009.4.44-49.
3. **Mikhaylovskiy MV, Fomichev NG.** Surgery of Spinal Deformities. Novosibirsk, 2002. In Russian.
4. **Mikhasevich NO, Tesakov DK, Tikhomirova TF, Pashkevich LA, Ilyasevich IA, Mukhlya AM.** Classification of congenital anomalies in the development of the spine. Military Medicine. 2007;(3):18–21. In Russian.
5. **Ulrikh EV, Mushkin AY, Gubin AV.** Congenital spine deformities in children: epidemiological prognosis and management. Hir. Pozvonoc. 2009;(2):55–61. In Russian. DOI: http://dx.doi.org/10.14531/ss2009.2.55-61.
6. **Arlet V, Odent T, Aebi M.** Congenital scoliosis. Eur Spine J. 2003;12:456–463. DOI: 10.1007/s00586-003-0555-6.
7. **Debnath UK, Goel V, Harshavardhana N, Webb JK.** Congenital scoliosis – Quo vadis ? Indian J Orthop. 2010;44:137–147. DOI: 10.4103/0019-5413.61997.
8. **Hefti F.** Congenita le Skoliosen: Halbwirbelresektion–Indikationen und Techniken. Kongresstage Ortopedie, Abstracts Kongress „Kinderorthop die" 2008:18.
9. **Hensinger RD.** Congenital scoliosis: etiology and associations. Spine. 2009;34:1745–1750. DOI: 10.1097/BRS.0b013e3181abf69e.
10. **King JD, Lowery GL.** Results of lumbar hemivertebral excision for congenital scoliosis. Spine. 1991;16:778–782.
11. **Shefi S, Soudack M, Konen E, Been E.** Development of the lumbar lordotic curvature in children from age 2 to 20 years. Spine. 2013;38:e602–e608. DOI: 10.1097/BRS.0b013e31828b666b.
12. **Ulrikh EV, Vissarionov SV, Mushkin AYu.** Surgery for congenital vertebral abnormalities using transpedicular fixation implants in infants. Digest of Spine Surgery Journal. 2013:1–8. Electronic resource. URL: http://www.spinesurgery.ru/Digest/Archive-DSSJ/DSSJ-2013/DSSJ-2013_82.html.

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